DRAFT

TEST/QA PLAN FOR THE VERIFICATION TESTING OF BAGHOUSE FILTRATION PRODUCTS

EPA Cooperative Agreement No. CR826152-01-2
RTI Project No. 7012-20
ETS Project No. 98-277

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PART A. PROJECT MANAGEMENT

A1.0 Title and Approval Sheet

A1.1 Title

Test/Quality Assurance Project Plan (Test/QAP) for the Verification Testing of Baghouse Filtration Products (BFPs).

NOTE: This Test/QA Plan has been structured to conform with the format of the EPA document *EPA Guidance for Quality Assurance Project Plans (EPA QA/G-5)*.

A1.2 Approval

This Test/QA Plan has been reviewed and approved by the following program participants:

RTI Program Manager:	J. R. Farmer	Original signed by J. R. Farmer	Date: 5/24/00
RTI Quality Manager:	R. S. Wright	Original signed by R. S. Wright	Date: 6/1/00
RTI Task Leader:	J. H. Turner	Original signed by J. H. Turner	Date: 5/31/00
RTI Quality Leader:	C. E. Tatsch	Original signed by C. E. Tatsch	Date: 6/1/00
ETS Task Leader:	J. C. Mycock	Original signed by J. C. Mycock	Date: 5/25/00
EPA Project Manager:	T. G. Brna	Original signed by T. G. Brna	Date: 5/24/00
EPA Quality Manager:	P. W. Groff	Original signed by P. W. Groff	Date: 5/24/00

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A3.0 Distribution List

The following is a list of individuals who will receive copies of the approved Test/QA Plan and any subsequent revisions.

Name	**Role**	**Organization**
Ted Brna	EPA Project Manager	EPA/APPCD
Paul Groff	EPA Quality Manager	EPA/APPCD
Jack Farmer	RTI Program Manager	Research Triangle Institute
Bob Wright	RTI Quality Manager	Research Triangle Institute
Jim Turner	RTI Task Leader	Research Triangle Institute
Gene Tatsch	RTI Quality Leader	Research Triangle Institute
John Mycock	ETS Task Leader	ETS, Inc.
John McKenna	ETS Verification Test Leader	ETS, Inc.
Sharon Winemiller	Test-Specific QA Officer	ETS, Inc.
Andy Hetz	Test-Specific Manager	ETS, Inc.

A3.1 List of Acronyms

The following is a list of acronyms that are used in this Test/QA Plan.

ADQ	Audit of Data Quality
ANSI/ASQC	American National Standard Institute/American Society for Quality Control
APCT	Air Pollution Control Technology
APPCD	Air Pollution, Prevention, and Control Division
ASQC	American Society for Quality Control
ASTM	American Society for Testing and Materials
BFPs	Baghouse Filtration Products
DQO	Data Quality Objective
EPA	United States Environmental Protection Agency
ESE	Environmental Sciences and Engineering
ETV	Environmental Technology Verification
FEMA	Filter Efficiency Media Analyzer
G/C	Gas-to-Cloth Ratio
LIMS	Laboratory Information Management System
LTG	LTG GmbH, Karlsruhe, Germany (Company that manufactures FEMA apparatus)
MSDS	Material Safety Data Sheet
NAAQS	National Ambient Air Quality Standards
NIST	National Institute of Standards and Technology
PE	Performance Evaluation
PM	Particulate Matter (Includes PM 2.5)
PM 2.5	Particulate Matter 2.5 micrometers and Smaller
QA	Quality Assurance
QAO	Quality Assurance Officer
QC	Quality Control
QMP	Quality Management Plan
RTI	Research Triangle Institute
SAC	Stakeholders Advisory Committee
SOP	Standard Operating Procedure
TSA	Technical Systems Audit
VDI	Verein Deutscher Ingenieure

A4.0 Project Organization

The U.S. Environmental Protection Agency (EPA) has overall responsibility for the Environmental Technology Verification (ETV) Program for Air Pollution Control Technology (APCT). Research Triangle Institute (RTI) is EPA's verification partner in this effort. The APCT program has selected Baghouse Filtration Products (BFPs) as a technology to be verified.

Management and testing within the BFP program is performed in accordance with procedures and protocols defined by a series of quality management documents. These include:
1. EPA's Quality Management Plan (QMP) for the overall ETV program,
2. RTI's Environmental Sciences and Engineering (ESE) Quality Manual,
3. the QMP for the overall APCT program,
4. the Generic Verification Protocol for Baghouse Filtration Products, and
5. a Test/QA Plan prepared by each participating testing organization.

ETS, Inc. has indicated an interest in being and demonstrated the necessary qualifications to be a participating testing organization for the BFP program and has prepared this Test/QA Plan to describe BFP testing under their responsibility.

As a participating testing organization, ETS will conduct laboratory tests on baghouse filtration products, analyze data, and prepare the verification reports and verification statements. The various quality assurance (QA) and management responsibilities are divided between EPA, RTI, and ETS key project personnel as defined below. The lines of authority between key personnel for this project are shown on the project organization chart in Figure 1.

A4.1 Roles and Responsibilities

Project management responsibilities are assigned to personnel from:
1. The United States Environmental Protection Agency (EPA),
2. Research Triangle Institute (RTI), and
3. ETS, Inc. (ETS).

A4.1.1 EPA

EPA is responsible for the overall Environmental Technology Verification (ETV) project oversight. The EPA Project Manager for the APCT program is Ted Brna. Verification responsibility encompasses approval of project plans and reports and ensuring that plans are implemented according to schedule. He requests the resources necessary to meet project objectives and requirements.

Paul Groff is EPA's APCT Quality Manager. He is responsible for ensuring that the EPA Quality and Management Plan (QMP) requirements are fulfilled and may perform quality audits and evaluations of participating organizations. He will be available to resolve any QA issues relating to conformance to EPA's QA requirements. Specific functions and duties of the EPA Quality Manager include approving the contents of this Test/QA Plan and subsequent revisions and reviewing QA reports prepared by RTI, including QA evaluations and audits. For further information concerning the EPA organizational structure, see EPA QMP Part A, Section 1.0 at http://www.epa.gov/etv/qmp.htm.

A4.1.2 RTI

RTI is responsible for the overall ETV APCT pilot program. Jack Farmer of RTI is the RTI Program Manager and will manage program activities and coordinate them with the Stakeholders Advisory Committee (SAC). Supporting the RTI Program Manager in matters of quality is Robert Wright who holds the position of RTI Quality Manager. For the BFP effort, Jim Turner is the RTI Task Leader, and Gene Tatsch is the RTI Quality Leader.

A4.1.3 ETS

ETS, as a participating testing organization, is responsible for the development and implementation of this Test/QA Project Plan. John Mycock is the ETS Task Leader. All individuals listed above are responsible for approving ETS' QMP and this Test/QA Plan, and for verifying ETS' E4 standing in accordance with the requirements set forth by the EPA Quality and Management Plan.

ETS, Inc. will perform BFP verification testing as a participating testing organization and will use the LTG Filtration Efficiency Media Analyzer (LTG/FEMA) test apparatus as specified in this Test/QA Plan to meet the specifications of the generic verification protocol for baghouse filtration products. ETS is responsible for specific test planning and execution as well as test data evaluation and reporting. Figure 1 details the project's organization.

A4.2 Verification Test Roles and Responsibilities

The verification test personnel will be organized into the following key areas of responsibility.

- Verification Test Leader
- Test-Specific Manager
- Test-Specific Quality Assurance Officer
- Test-Specific Team Leader

The responsibilities of each of the above positions are detailed below.

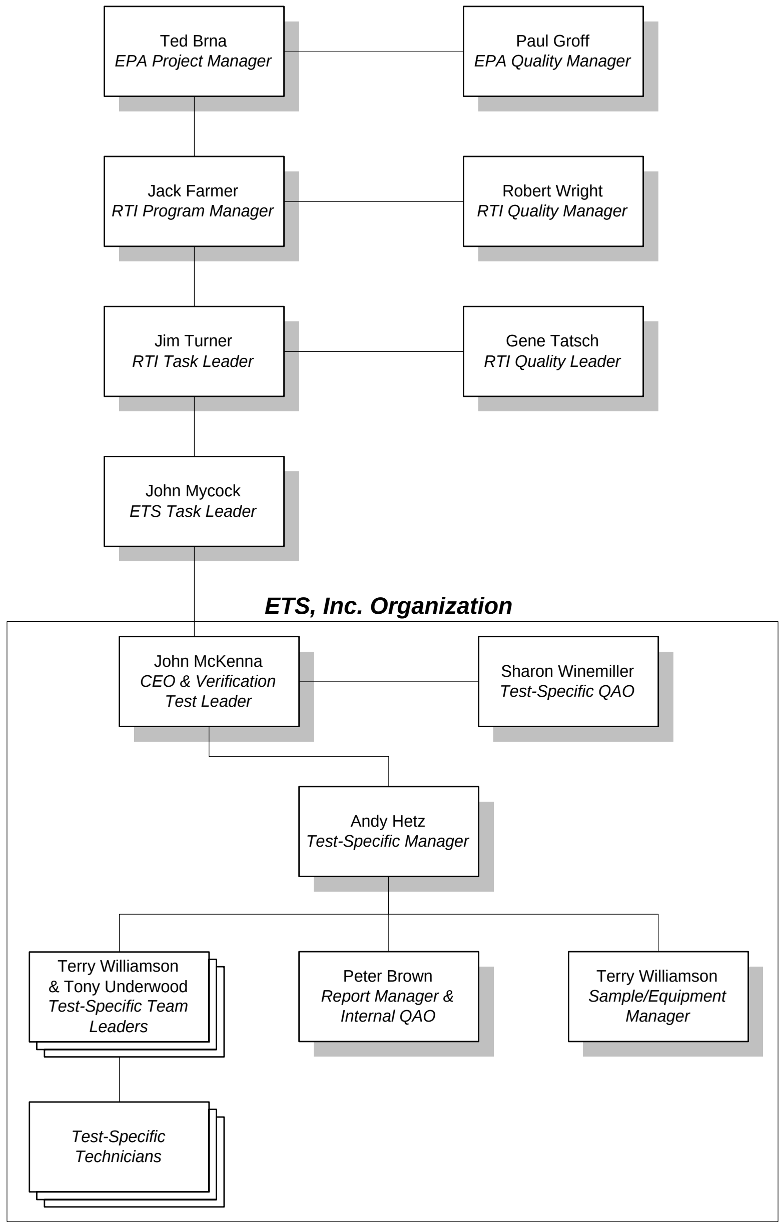

Figure 1. Project Organization

A4.2.1 Verification Test Leader

John McKenna will serve as the overall ETS Verification Test Leader and is the final link in the ETS chain of command. The Verification Test Leader will serve as backup to the Test-Specific Manager for technical support and any communications between the involved parties and ETS. The Verification Test Leader will provide scheduling and administrative support to the testing program. McKenna will assist in the review and approval of all draft verification reports and draft verification statements generated from this project. The Verification Test Leader is also responsible for any corrective action implementation procedures that might arise from performed audits.

A4.2.2 Test-Specific Manager

Andy Hetz will serve as the Test-Specific Manager. The Test-Specific Manager's duties include supervising the verification testing procedures, assisting in the development of draft project reports, providing on-site management, and overseeing equipment handling and test execution. The Test-Specific Manager will also review all aspects of the testing program to ensure proper communication among all parties, review the sampling and recovery procedures as executed, and provide on-site data review. The Test-Specific Manager is responsible for the verification of the test data, spreadsheets, template accuracy, and preparation of the draft verification statement and the draft verification report.

A4.2.3 Test-Specific Quality Assurance Officer

Sharon Winemiller will be the Test-Specific QAO. The Test-Specific QAO will work independently of the project management team and is responsible for procedures that determine if the verification test is being conducted in accordance with QA/QC requirements. The Test-Specific QAO is also responsible for inspections and technical assessments to verify compliance with QA/QC goals. The Test-Specific QAO will independently review test data and laboratory results, and will assist in the preparation of the draft verification reports and draft verification statements that are generated from this project.

A4.2.4 Report Manager

Peter Brown will be responsible for the draft verification report and draft verification statement development and data validation. The Report Manager will also perform duties associated with internal QAO for field services. Peter Brown’s function as internal QAO is to double-check the data received by the field testers. The Report Manager supervises the review of all raw test data and checks all spreadsheet templates for accuracy. He reports any inconsistencies to the Test-Specific Manager and the Test-Specific QAO.

A4.2.5 Sample/Equipment Manager

Terry Williamson will receive and secure all incoming samples and is responsible for the correct preparation of all sampling dust and filter media awaiting verification testing. The Sample/Equipment Manager is also responsible for obtaining and retaining in stock reference polyester media and aluminum oxide test dust for calibrations and comparisons. The Sample/Equipment Manager confirms a direct chain-of-custody and reviews all sample identification numbers against the actual test data sheets for accuracy. Any discrepancies are reported to the Test-Specific Manager. Terry Williamson also distributes the samples to the appropriate verification testing areas.

In the event that key personnel changes need to be made, the APCT Program Office at Research Triangle Institute will be informed.

A5.0 Problem Definition

(The generic verification protocol provides extended discussions on problem definition from which portions of the following have been extracted.)

A5.1 Background

Baghouses and their accompanying filter media have long been one of the leading particulate control techniques for industrial sources. Increasing emphasis on higher removal efficiencies has helped the baghouse to be continually more competitive when compared to other generic control devices. With the issuance of the new PM 2.5 NAAQS, owners/operators of existing baghouses will have to consider fine particulate removal effectiveness when making decisions on purchasing baghouse filtration media.

Since EPA has issued a new National Ambient Air Quality Standard (NAAQS) for 2.5 μm primary particulate matter (PM 2.5), *40 CFR part 50, Section 50.7*, a strong interest exists in verifying the performance of control systems for fine particulate matter (PM).

A5.2 Problem Statement

At present, there is no independent, objective test method for characterizing the performance of baghouse filter devices. Owners/operators wishing to evaluate baghouse performance rely on test information that is provided by vendors. Hence, there is a need for independently verified performance data for baghouse components. Since there are many different physical configurations that can be used in the design of a baghouse, there is a large but limited offering of filter media from which the bags are generally fabricated. Hence, characterization of the performance of the filter media used in bag fabrication is a more general solution, and it is amenable to less costly test designs. For this reason, testing of the filter media itself is the subject of this verification technology.

The specified test equipment makes it possible to conduct measurements under defined conditions with regard to, among other parameters, filtration velocity (G/C), dust loading, particle size distribution, and cleaning requirements. Controlled conditions make it possible for the users to make informed decisions concerning the performance of baghouse filtration media.

A5.3 Objective

Based on discussions with the BFP technical panel, the objective of the ETV Baghouse Filtration Products (BFP) program is to produce for the public credible test reports and verification statements regarding PM 2.5 (particulate matter that is 2.5 μm diameter or less) removal performance by tested baghouse filtration media. Testing will be performed according to this Test/QA Plan which responds to the specifications of the *Generic Verification Protocol for Baghouse Filtration Products (November 1999)* and the SOP, Appendix C, which is derived from VDI Method 3926, Part 2, *"Testing of Filter Media for Cleanable Filters Under Operational Conditions,"* as described in section 2.3 of the generic verification protocol.

A6.0 Project/Task Description and Schedule

(The generic verification protocol provides extended discussions on project/task descriptions from which portions of the following have been extracted.)

The purpose of this Test/QA Plan is to document the detailed procedures that ETS will follow during the verification testing of baghouse filtration products. The test apparatus that will be used to determine filtration media performance, and the basic approach for determining PM 2.5 outlet concentration, is derived from VDI method 3926. The complete SOP that includes these modifications is provided in Appendix C.

A6.1 Description of the Work to be Performed

The verification test will be a 5-day test to verify the performance of samples of commercially ready baghouse filtration media relative to PM 2.5. A verification test will include three identical test runs, on three separate sample specimens. Each verification test run will include a 10,000 pulse conditioning period, a 30 pulse recovery period, and a performance evaluation test period spanning 6 hours. At the conclusion of the three verification test runs the sample media performance evaluation results, in the form of a Verification Report and Verification Statement, will be prepared by ETS for review by the APCT program and review and approval by EPA. The focus of the verification testing is to determine the value of the verification parameters that are listed in Section A6.1.1.

A6.1.1 Measurements that are Expected During the Course of the Project

The filtration and cleaning conditions are specified to be comparable with conditions that prevail in actual baghouse operation. Detailed measurement procedures can be found in the SOP located in Appendix C.

As specified in the approved *Generic Verification Protocol for Baghouse Filtration Products (November 1999)* the BFP Verification parameters will consist of:

- outlet particle concentration, PM 2.5 (g/dscm [gr/dscf]),
- outlet particle concentration, total mass (g/dscm [gr/dscf]),
- average residual pressure drop (3 seconds after cleaning pulse) during the 6-hour performance test period (cm w.g [in. w.g]),
- average filtration cycle time during the 6-hour performance test period (s), and
- mass gain of verification sample filter at test completion (g), (measured from new fabric filter mass, after 10-pulse cake removal, as stated in VDI method 3926).

A6.1.2 Schedule for the Work Performed

One verification test includes test runs on three identical, randomly selected media samples supplied by the manufacturer requesting the test. The testing schedule for each test run requires approximately 24 hours. It commences with a conditioning period of 10,000 rapid-pulse (i.e., 3 second) cycles to simulate long term usage. Upon completion of the conditioning period, a recovery period of 30 normal (i.e., when the pressure drop across the media reaches 4 inches w.c.) pulses is initiated. Once the recovery period is concluded, a performance test period lasting 6 hours is initiated.

A6.1.3 Records and Reports

Within 30 days from the completion of the verification test, a draft verification report and a draft verification statement will be prepared by the Report Manager and submitted to the APCT Program Office for review. The report will include, but not be limited to, a complete description of the test method and equipment, a summary of the test data that were recorded during the execution of the test, all calibration and maintenance data, which will include which instruments are being calibrated, raw calibration data, analyzer identification, calibration dates, calibration standards used and traceability, identification of calibration equipment used, and staff performing the calibrations, and a quality assurance section detailing all technical assessments that were performed and all quality control reports. As part of the draft report, the draft verification statement will be prepared. The statement will be a short summary of the detailed verification report. The verification report and a verification statement format will follow that found in Appendix A and B of the *Generic Verification Protocol for Baghouse Filtration Products (November 1999).*

For further information on records and documentation management refer to Section A9.0. Refer to section A9.2.2 and A9.2.3 for more detailed information pertaining to the verification statement and the verification report, respectively.

A7.0 Quality Objectives and Criteria for Measurement Data

Quality assurance (QA) encompasses the organization and program within which quality control (QC) activities are performed. Quality control activities accompany all verification testing activities and procedures to provide control of data quality and to quantify the quality of data resulting from those procedures. Each verification test will include QA activities as specified in this section.

A7.1 Quality Objectives

The Data Quality Objectives (DQOs) specified in Table 1 relate to each run and detail the control limits that define a valid test. A test may be invalidated due to operator error, as well as events such as breakage, equipment failure, or failure to achieve the specified DQOs. In the event that a critical measurement is invalidated, the run will be repeated on a new test sample. The decision to repeat a test run will be made by the Test-Specific Team Leader and the Test-Specific Manager at the time of the error. A review of completeness for each test run will be made by the Test-Specific Team Leader in the daily test logs.

Annual calibration procedures will be performed as described in the *Generic Verification Protocol for Baghouse Filtration Products (November 1999)*, attachment 2.

For the initial phase of BFP verification testing, these specifications are considered to be draft objectives: failure to achieve them will require:

-Review of the procedures by the ETS team,
-Documentation of any deviations,
-Whether the deviations were significant,
-Verification in report and statement whether the DQOs were attained,
-Calculation of uncertainty of the verification parameter, and
-Consultation with the APCT Program Office.

If measurement objectives are attained, the DQOs are attained. The measurement objectives are assumed to be attained if a propagation of errors analysis is performed and all solutions are within the specified ranges. Refer to *Attaining the Quality Objectives for the Mean Outlet Particle Concentration (PM 2.5 or total)*, Appendix A for a propagation of errors analysis. Section B.5 on quality control requirements describes the actions necessary to attain the measurement objectives.

Table 1. Data Quality Objectives

Verification Parameter	Quality Objective [%]	**Measurement Objectives for Associated Critical Measurements** Residual Pressure *[cm w.g.]*	Flowrate - Raw Gas Pump *[m^3/hr]*	Flow rate - Clean Gas Pump *[m^3/hr]*	Mass Gain *[g]*	Time *[sec]*
Wt. gain of ref. fabric *[g]* [with respect to APCT reference value]	±10					
Maximum pressure drop [with respect to APCT reference value]	±10					
Mean Outlet Particle Concentration, PM 2.5 *[g/dscm]*	±15		± 0.23	±0.06	± 0.00005	
Mean Outlet Particle Concentration, Total Mass *[g/dscm]*	±15		± 0.23	±0.06	± 0.00005	
Average Residual Pressure Drop *[cm w.g]*	± 5	± 0.25				
Mass Gain of Filter Sample *[g]*					± 0.05	
Average Filtration Cycle Time *[sec]*	± 1					± 1

A7.2 Measurement Performance Criteria

Table 2 presents the test specifications for the proposed test program. This table shows the acceptable levels of bias and precision needed for a valid test, along with the methods used to determine these measurements. Refer to section D4.0 for further information pertaining to accuracy (bias) and precision. For more information related to determining accuracy and precision, refer to sections D4.1 and D4.2. Accuracy is the degree of agreement of a measurement (or average of measurements) with an accepted reference or true value. Precision is a measure of instrumental mutual agreement of replicate measurements. Completeness is a measure of valid data compared to the amount that is expected under correct operating conditions. Section B.5 gives more detail on the performance criteria for individual measurements**.**

A8.0 Special Training Requirements/Certification

All participants of the verification test program will have completed required training courses prior to being assigned to the BFP verification test program. The results of the training programs will be maintained in the individual's LTG/FEMA training file. The Test-Specific Manager and the Verification Test Leader have extensive experience in filtration efficiency measurements, understand filtration mechanisms that lead to particle collection in filters, are familiar with the characteristic shape of filtration efficiency curves, and are knowledgeable of particle transport in sample lines.

The Test-Specific Team Leaders must be thoroughly familiar with operation of the specified BFP verification test apparatus, use of flow measurement devices, and operation and sampling methods associated with use of the impactor.

A8.1 Training

ETS provides two training programs that are applicable to the test program. Upon employment, each field employee is required to attend a safety training program. Once per year, ETS offers a sampling methods training course to all new employees. The 1-week program indoctrinates the employees to the basics of the most common test methods.

Training also includes orientation to the data sheets and equipment available at ETS. Each employee is informed of the ETS policies and procedures to ensure that accurate and complete test data are obtained. Each employee is given a training manual that includes sample data sheets, and ETS policies and procedures. At the completion of the course, each employee is tested and must achieve a minimum score of 70 % or repeat the program. The test results are kept in the employees personnel file.

Table 2. Test Specifications

Constant Parameter	Nominal Value	Acceptable Bias*	Acceptable Precision**	Instrument	Frequency
Test Dust Particle Size Percentage (ALCOA Aluminum Oxide A -152SG)	60.0 % <2.5 μm (Avg. 3 runs)	± 10.0 %	± 0.0001 g Filter mass Gain per weighing	Andersen Impactor, Model 50-900 (as Determined by Analytical Balance)	Quarterly and Each New Batch
Test Dust Mass Mean Aerodynamic Diameter (ALCOA Aluminum Oxide A-152SG)	2.0 μm (Avg. 3 runs)	± 0.5 μm	± 0.0001 g Filter mass Gain per weighing	Andersen Impactor, Model 50-900 (as Determined by Analytical Balance)	Quarterly and Each New Batch
Filter Sample Diameter, mm (in.)	150 (5.88)	± 1.6 (1/16)	± 1.6 (1/16)	Filter Cutter	Each Test Specimen
Inlet Raw Gas Flowrate, m^3/hr (cfm)	5.8 (3.4)	± 0.3 (0.2)	± 0.01 (0.006)	Mass Flow Controller	Each Test. Calibrate @ 6 Month
Filtration Velocity (G/C Ratio)***, m/hr (fpm)	73.1 (4.0)	± 3.6 (0.2)	± 1.8 (0.1)	Mass Flow Controller and Filter Sample Area	Each Test. Calibrate Every 6 Months
Pressure Drop Trigger for Cleaning	1,000 Pa (4.0 in. w.g)	±0.127 cm w.g (0.05 in. w.g)	± 0.127 cm w.g (0.05 in. w.g)	Pressure Transducer	Each Test
Rapid Pulse Cleaning Cycles (0 - 10,000), sec	3	± 1	± 1	Datalogger Clock	Beginning of Each Test
Pulse Duration, ms	50.0	± 5.0	± 1.0	Pulse Regulator	Each Test
Pulse Cleaning Pressure, MPa (psi)	0.52 (75.0)	± 0.03 (5.0)	± 0.007 (1.0)	Pulse Regulator	Each Test
Gas Temperature, °F	74	± 4	± 1	Thermocouple	Each Test
Inlet Dust Concentration, g/dscm (gr/dscf)	34.4 (15.0)	± 3.4 (1.5)	± 0.22 (0.1)	Dust Load Cell and Mass Flow Controller	Continuously
Minimum Aggregate Mass Gain for Impactor Substrates and Filter, g	0.01		± 0.0005	Andersen Impactor, Model 50-900 (as Determined by Analytical Balance)	Each Test
Charge Neutralizer					Verify Continued Effective Performance of Device Monthly
Dust Feeder Operation, g/hr	206	± 20	± 20	Dust Load Cell	Each Dust Loading Operation

* Acceptable bias = For the test to be valid, the instrument reading must record a value within listed range. For example, the ±4 degrees accuracy means that the temperature reading of the gas must be within the range of 70 to 78° Fahrenheit.
** Precision = The precision of the instrument reading. For example the thermometer or thermocouple that is used to measure temperature must record temperature within 1 degree of actual.
*** Filtration Velocity (G/C) = Sample Gas Stream Volume / Area of Filter Sample = 0.76 scfm / 0.19 ft^2 = 4.0 fpm = 4/1 G/C Ratio. 1.29 m^3/hr / 0.01762 m^2 = 73.1 m/hr.

In addition, all Test-Specific Team Leaders must complete a 16-hour LTG/FEMA operation training program by a LTG representative or an appropriate ETS designate, three successful 30-cycle reference media tests, as stated in the Generic Verification Protocol Section 2.4, and one complete verification test run (one conditioning period, recovery period, and performance period) using the reference media and reference dust prior to being considered a qualified LTG/FEMA apparatus operator.

A8.2 Certification

ETS, Inc. has submitted its baghouse filtration products quality management plan to comply with the requirements of the *American National Standard, Specifications and Guidelines for Quality Systems for Environmental Data Collection and Environmental Technology Programs (ANSI/ASQC E4-1994)*. ETS' quality management plan was submitted on June 18, 1999, and is on file with the APCT Program Office. ETS, Inc. also complies with the APCT and EPA Quality Management Plans. ETS may be audited at any time by EPA, its representatives, or the APCT Program Office to ensure compliance with these documents and that all requirements are met.

There is no special certification that the ETS testing staff must obtain prior to operating the LTG/FEMA apparatus. However, the testing staff must complete the training requirements listed in section A8.1 prior to operating the test apparatus.

A9.0 Documentation and Records Management

Proper documentation and recordkeeping is critical to ensure quality data. The proper reporting format, combined with data validation, facilitates investigation into the quality of the data and of the report and statement generated for the project. All verification reports and verification statements will be submitted to the APCT Program Office in electronic format (Word or WordPerfect). All records and documents will be maintained at ETS for 7 years from the date of final payment from the APCT Program Office.

A9.1 Data Reporting Packages

Specific documentation and recordkeeping requirements for this project are separated into test operation records and data handling records.

A9.1.1 Test Operation Records

The following test operation records will be an integral part of the test program.

- **Chain-of-Custody Records** - Chain-of-custody sheets will be completed to allow tracking of the samples from collection through verification test completion. This action minimizes any chance of sample loss or possibility of sample tampering.

- **Material Safety Data Sheets** - MSDS documentation for the reference dust will be included in the report.

- **Daily Test Logs** - Accurate and complete logs will be kept on all daily activities. The Test-Specific Team Leader is responsible for completing the logs. These logs document all activities, and include sampling times, process delays, equipment failures, any deviations from this Test/QA Plan or standard testing practices and procedures, and all quality control measurements that were conducted. The test operator records test data and notes on daily test logs prepared specifically for these tests (presented in SOP, Appendix A). The sheets are designed to prompt the test operator for all required test information:
  - Testing date, time, and operator.
  - Manufacturer and model number of filter samples.
  - QA checks on the equipment and data.
  - Test conditions (temperature, relative humidity, atmospheric pressure, flow rate).
  - Data quality checks.

- **Sample Label** - Sample labels will be applied to all samples that are accepted for the verification test. Sample labels will be applied to track sample testing and to minimize chance of possible loss and mixup.

- **Record-of-Consumables** - The record-of-consumables will track the quantities of consumable items that will be used in the verification test, the expiration date (if applicable), and the required consumable test dates

.

- **Inspection/Acceptance Requirements** - The Inspection/Acceptance Requirements form for critical supplies and consumables will track the test requirements, frequency, and acceptance status of the reference materials and dust. This form will also record the storage condition for each material.

- **Log for Tracking Supplies and Consumables** - The log for tracking supplies and consumables will contain the arrival dates of all consumable items, the required testing for each item, and the expiration date (if applicable).

A9.1.2 Data Handling Records

Specific measures will be used to track and ensure the generation of quality data. These records will convert raw data into reportable quantities and units, incorporate proper use of significant figures, and provide data validation to show that QC criteria have been met.

- **Daily Test Logs** - Raw test data will be summarized at the completion of each test day. All hand-recorded data will be recorded using indelible ink. A single line will be drawn through recording errors and initialed by the responsible person. Standardized spreadsheets will be used to create computer generated summaries.

- **Data Review Records** - The test data spreadsheets are released to the report manager at the conclusion of the test program. The test files are reviewed by the report manager, any errors are corrected, and the files are given a unique file identification under a standardized identification system. Each verification test series will be labeled with a file number identifying the year, followed by the ETS BFP verification testing contract number, and a test specific identification. For example, 99-577BFP1-A1.

The appropriate laboratory data are entered into the spreadsheets, the results reviewed for reasonableness, and the files saved. Two copies of the documents will be created. One copy will be maintained at ETS in a fireproof cabinet, and a second copy will be sent to the APCT Program Office for storage.

- **QA/QC Data Records** - The Report Manager and Test-Specific QAO review the data and examine any data discrepancies or outlying data points. Any corrective actions are recorded and documented. The Internal QAO hand-calculates one data set from each type of sampling and compares it to the computer generated spreadsheets for accuracy. This calculation check is included in the final data package. A comparison of the quality control measurements with the data quality objectives is also performed and included in the final data package.

A9.2 Data Reporting Package Format and Documentation Control

The verification report and the verification statement will be that found in Appendices A and B of the *Generic Verification Protocol for Baghouse Filtration Products (November 1999).* The contents of the supporting data reporting packages will be consistent with the requirements and procedures used for data validation and data assessment described in this Test/QA Plan. All records taken to achieve the objective of the project and the QA performance functions will be components of the data reporting packages.

A9.2.1 Document Control

All test documents will remain in the custody of the Test-Specific Team Leader from their generation until their release to the Report Manager. Copies of all data and record sheets will be made, which will be used as working models to generate the draft verification report. A list of all original data and record sheets will be made, and the originals filed in a cabinet located in a locked room. Access to the storage room is limited to key personnel. The Report Manager has custody of all documents from test completion until the draft report is completed.

The draft verification report and draft verification statement are reviewed at ETS by the Task Leader, the Verification Test Leader, and the Test-Specific QAO. Following release by ETS, they are reviewed by the APCT Program Office, including the RTI Task Leader and Quality Leader, and the Program Manager and Quality Manager. Once all issues have been resolved the APCT Program Manager will send the verification report and verification statement to the EPA Project Manager for review and approval. The final Verification Statement will be signed by the Director of EPA's National Risk Management Research Laboratory. Two copies of all project information will be archived. The original copy of the report and statement will be stored at ETS in a fireproof cabinet in a limited access storage room. All computer files, spreadsheets, figures, tables, schematics, and report texts will be archived in this room. The second copy will be sent to the APCT Program Office for storage. Computer files are generally kept on the ETS network for 6 months after the conclusion of the test program. All archived files and reports will be kept in ETS' custody for a minimum of 7 years after the final payment of the assistance agreement between ETS and the APCT Program.

A9.2.2 Verification Statement

The Verification Statement, which is a brief summary of the verification test report, will include the following information:

- Product manufacturer,
- Model or style number,
- Brief description of tested filter media,
- Test date and location,
- Testing firm,
- Summary test conditions
- Outlet particle concentration (PM 2.5 and total mass),
- Average residual pressure drop during performance test period,
- Average filtration cycle time during performance test period,
- Mass gain of sample media at test completion,
- Number of cleaning cycles during 6-hour performance test period, and
- Non-standard test conditions (if applicable).

The verification statement will also include a statement that the RTI Quality Manager has reviewed the test results and the QC data and has concluded that the data quality objectives given in the generic verification protocol have been attained.

A9.2.3 Verification Report

The Verification Report is a fully documented test report containing a complete description of the test method and equipment, and the results of all measurements and QC and QA activities. The Verification Report will include:

- All test specimen information, as stated in Verification Statement, plus
- Data from the reference media,
- Test data as collected,
- Results of control tests,
- Quality assurance results,
- Equipment calibration data,
- Comparison between DQOs and test results, and
- Deviation from the approved generic verification protocol (requires APCT approval).

In addition the Verification Report will include all test conditions and operational data including, but not limited to, gas velocity, gas volume, cleaning pressure drop trigger, and relative humidity.

The Verification Report will also provide an overview of the test methods employed, facilities, and equipment used. Data will be presented in a format to permit ready comparison with DQOs.

A discussion of problems encountered and an explanation of how these problems were resolved will also be included.

After review of the test results and QC data presented in the draft verification report, the RTI Quality Manager will prepare a QA section for inclusion in the report regarding the attainment of the data quality objectives. ETS, Inc. will maintain one copy of all archived files and reports for a minimum of 7 years after the final payment of the assistance agreement between ETS and the APCT Program Office. The ETS copy will be maintained on the ETS premises in a fireproof cabinet. A second copy will be sent to the APCT Program Office for storage.

An example copy of the Verification Report and Verification Statement is included in Appendices A and B of the *Protocol for Verification Testing of Baghouse Filtration Products*.

A9.2.4 QA/QC Reports

After the completion of verification tests, control test data, sample inventory logs, calibration records, and certificates of calibration will be stored with the verification test data at the ETS facility. A duplicate copy will be sent to the APCT Program Office. Calibration records will include such information as the instrument being calibrated, raw calibration data, calibration equations, analyzer identifications, calibration dates, calibration standards used and their traceabilities, identification of calibration equipment used, and staff conducting the calibration. Final reports of self-assessments and independent assessments (i.e., technical systems audits, performance evaluations, and audits of data quality) will be retained in the APCT Program Office with a duplicate copy kept at ETS. Each verification report and verification statement will contain a QA section, which will describe the extent that verification test data comply with data quality objectives.

PART B. MEASUREMENT/DATA ACQUISITION

B1.0 Process Design (Experimental Design)

Table 1 lists the critical measurements that are associated with the BFP verification test. Critical measurements are required to achieve project objectives. Table 2 identifies the BFP verification test conditions. The BFP test conditions must be met and maintained to perform a valid test series.

B1.1 Test Apparatus

The BFP test apparatus provides an appropriate baghouse filter media test environment. This equipment allows the user to conduct measurements of filter performance under defined conditions with regard to the filtration velocity (Gas-to-Cloth ratio, G/C), particle size distribution, and cleaning requirements. Filtration and cleaning conditions can be varied to simulate conditions that prevail in actual baghouse operations.

The test apparatus (see Figure 2) consists of a brush-type dust feeder that disperses test dust into a vertical rectangular duct (raw-gas channel). The dust feed rate is continuously measured and recorded via an electronic scale located beneath the dust feed mechanism. The scale has a continuous readout with a resolution of 10 g. A radioactive polonium 210 alpha source is used to neutralize the dust electrically before its entry into the raw-gas channel. An optical photo sensor monitors the concentration of dust and ensures that the flow is stable for the entire duration of the test: the optical photo sensor does not measure concentration. A portion of the gas flow is extracted from the raw-gas channel through the test filter, which is mounted vertically at the entrance to a horizontal duct (clean-gas channel). Two vacuum pumps maintain air flow through the raw-gas and clean-gas channels. The flow rates, and thus the G/C through the test filter, are kept constant and measured using mass flow controllers. A pressure transducer is used to measure the average residual pressure drop of the filter sample. The pressure transducer measures the differential pressure across the filter samples 3 seconds after the cleaning pulse. The pressure drop measurements are averaged as stated in the Appendix C, SOP, section 4.4.1. High efficiency filters are installed upstream of the flow controllers and pumps to prevent contamination or damage caused by the dust. The cleaning system consists of a compressed-air tank set at 0.52 MPa (75 psi), a quick-action diaphragm valve, and a blow tube (25.4 mm [1.0 in.] dia.) with a nozzle (3 mm [0.12 in.] dia.) facing the downstream side of the test filter.

B1.2 Test Design

Each Verification Test consists of three test runs. Each test run consists of three sequential phases or test periods: a conditioning period, a recovery period, and a performance test period. The G/C and inlet dust concentrations are maintained at 73.1 ± 3.6 m/hr (4.0 ± 0.2 fpm) and 34.4 ± 3.4 g/dscm (15.0 ± 1.5 gr/dscf), respectively, throughout all phases of the test.

To simulate long-term operation, the test filter is first subjected to a conditioning period, which consists of 10,000 rapid-pulse cleaning cycles under continuous dust loading. During this period, the time between cleaning pulses is maintained at 3 seconds. No filter performance parameters are measured in this period. Within the first test run, a quick-check is performed during the conditioning period. Refer to SOP Section 4.3.4 for the procedure.

The conditioning period is immediately followed by a recovery period, which allows the test filter to recover from rapid pulsing. The recovery period consists of 30 normal filtration cycles under continuous dust loading. During a normal filtration cycle, the dust cake is allowed to form on the test filter until a differential pressure of 1,000 Pa (4.0 in. w.g) is reached. At this point, the test filter is cleaned by a pulse of compressed air from the clean-gas side. Immediately after

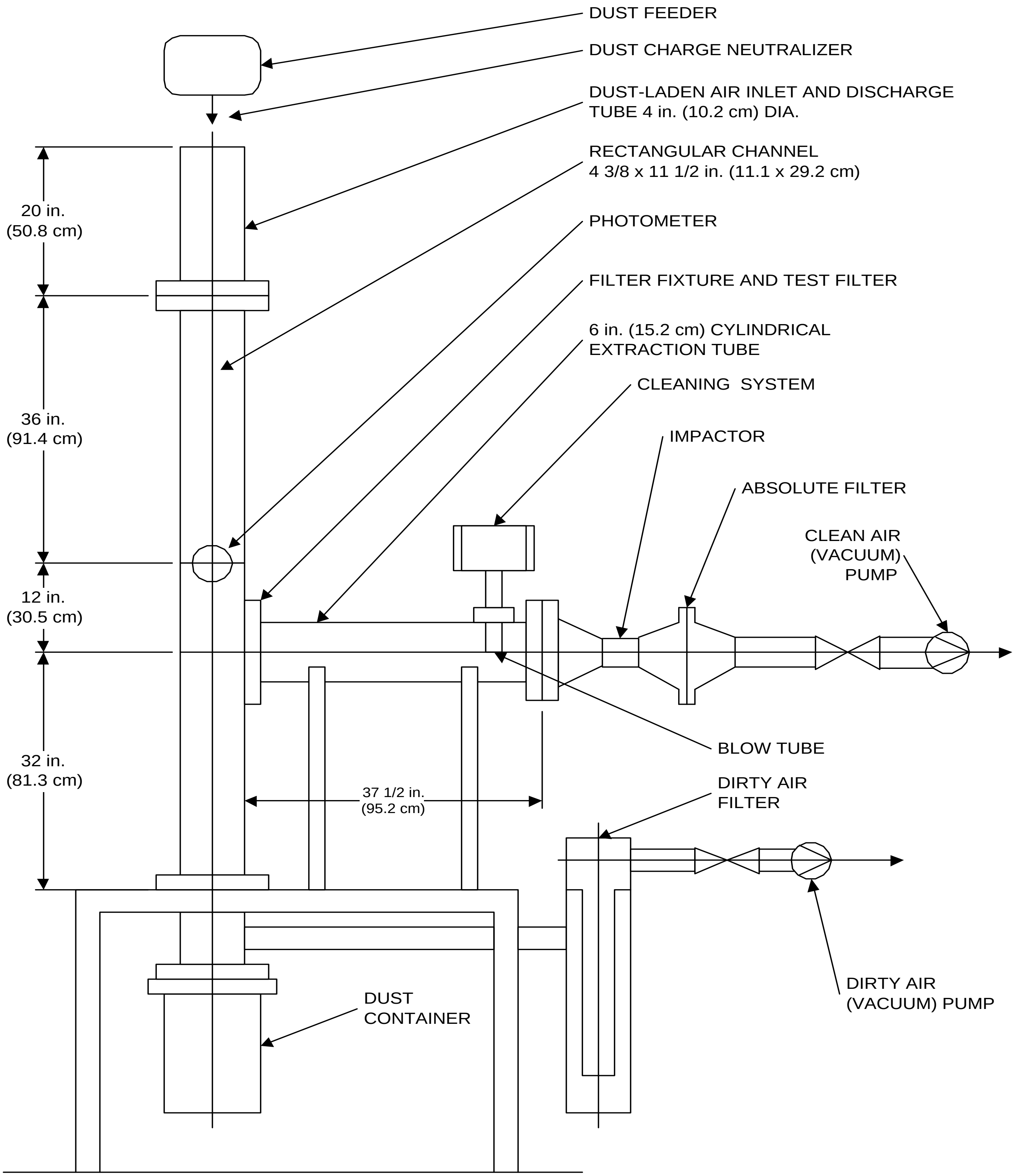

Figure 2. LTG/FEMA Test Apparatus

pulse cleaning, the pressure fluctuates rapidly inside the test duct. Some of the released dust immediately re-deposits onto the test filter. The pressure then stabilizes and returns to normal. Thus the residual pressure drop across the test filter is measured 3 seconds after the conclusion of the cleaning pulse. Pressure drop is monitored and recorded continuously throughout the filter media recovery and performance test periods of each test run.

Performance testing occurs for a 360-minute period immediately following the recovery period, (a cumulative total of 10,030 filtration cycles after the test filter has been installed in the test apparatus). During the performance test period, normal filtration cycles are maintained and, as in the case of the conditioning and recovery periods, the test filter is subjected to continuous dust loading. Outlet mass and PM 2.5 dust concentrations are measured using an inertial impactor located downstream of the test filter at the end of the horizontal (clean-gas) duct. The impactor consists of impaction stages needed to quantify total particulate matter and PM 2.5 concentrations. The weight gain of each stage's substrate is measured with a high resolution analytical microbalance capable of measurement to 0.00001 g. Refer to Appendix C, SOP, for detailed verification test sampling procedures.

B2.0 Sampling Methods Requirements

B2.1 Filter Media Samples

Verification test filter media samples will be supplied directly to ETS, Inc. from the manufacturer. The samples will be accompanied by a letter signed by the manufacturer's CEO, president, or other responsible corporate representative, attesting that the media samples were randomly selected as to production run and roll location and are representative of what is supplied to the commercial market. Included in the signed letter will be a description of how the samples were selected. The manufacturer will supply ETS, Inc. with nine samples (46 x 91 cm [18 x 36 in.]); from these ETS, Inc. will select three samples to prepare test specimens. A chain-of-custody form will be filled out when the samples are received by ETS.

For purposes of product identification (by, for example, ETS, Inc., auditors, end-users, and local inspectors), the manufacturer must label or tag the filter media in a reasonably permanent manner to show the name of the manufacturer, type of filter media, all applicable model numbers pertaining to the sample, cake side, and date (year and month) of manufacture; if this information is not present, ETS, Inc. will reject the media for BFP verification testing.

B2.2 Impactor Filter Samples

Impactor samples will be purchased from the impactor manufacturer. Each impactor substrate filter will be preweighed and then stored in aluminum foil according to the procedures detailed in the SOP. Each piece of aluminum foil will be labeled to match its corresponding substrate filter. Each label will be made with permanent marker directly on the foil to avoid extra label weight.

B3.0 Sample Handling and Custody Requirements

A key issue in the verification process is the integrity of the sample tested. The goal of sample preparation and management is to ensure that proper sample custody and management practices are implemented to respond to this issue. Sample preparation consists of providing the proper test specimen for verification testing purposes. Sample management is the overall process by which samples are controlled, transferred, handled, and stored from the time of collection through analysis. Sample management refers to those activities aimed at ensuring sample integrity. Chain-of-custody involves establishing accountability for the sample, documenting how the sample is received, tracked, and stored, and defining who has access to the samples and who handles the samples.

Sample Chain-of-Custody: The purpose of sample chain-of-custody is to ensure the traceability of the handling and possession of each sample from the time of collection through the completion of analysis. The following information is requested when samples are shipped to ETS: ETS' name and address, sample identification and letter of sample integrity as described previously in Section B2.0, test that will be conducted, and the signatures of all persons involved in the chain of custody. A log generated by the recovery personnel and reviewed by the Test-Specific Team Leader is utilized for chain-of-custody. Examples of a chain-of-custody record can be found in Appendix B.

Sample Labels: Exclusive test method sample labels are generated for each incoming sample utilizing a sample management services database program. To create labels, the client contract number is entered, the test method and the number of sets of labels are specified, and sample identification numbers are assigned. The labels are then printed and applied to the samples. These labels must be used on each sample and will be used in sample number order to avoid confusion on a test job. Labels for the impactor filters are written with marker directly on the storage foil so that measurements do not include additional label weight.

B4.0 Analytical Methods Requirements

To simulate dust loading conditions within a baghouse ETS will be using the procedure specified in Appendix C. The performance of the fabric will be determined relative to the verification parameters listed previously in Section A6.2.1.

B4.1 Materials and Apparatus

The required materials that will be used to perform an accurate and valid test are listed below. Any substituted equipment will be comparable to the equipment and performance requirements of the following list and will receive APCT approval prior to verification testing and will also be noted in the verification report. For greater detail pertaining to the following equipment, refer to Appendix C, which contains the verification test SOP.

The LTG/FEMA test apparatus, based on the German VDI method 3926 (see Attachment A of Appendix C), provides an appropriate baghouse filter media test apparatus. This equipment allows the user to measure filter performance under defined conditions with regard to the filtration velocity (G/C), particle size distribution, and cleaning requirements. Filtration and cleaning conditions can be varied to simulate conditions that prevail in actual baghouse operations. For a discussion of components within the test apparatus, refer to section B1.1. For a list of equipment makes, model numbers, and ranges proceed to Table 3 .

B4.1.1 Test Apparatus

ETS will perform the BFP verification tests using the specified LTG/FEMA test apparatus. The APCT-approved components used with the BFP test apparatus consist of the following items:

- Electronic data logger or programmable logic controller.
- Dust feed weight measurement device.
- Dust feed hopper.
- Thermocouple.
- Pressure transducer.
- Removable clean gas channel.
- Manual pulsing function.
- Test dust (aluminum oxide).

B4.1.2 Test Dust

ETS has obtained Alcoa A152-SG as the verification test dust to comply with the requirements specified in the *Generic Verification Protocol For Baghouse Filtration Products (November 1999)*. The shipment of Alcoa A152-SG will be tested for conformance with requirements of the generic verification protocol. The Alcoa A152-SG must conform to the specification of greater than 99.6% Al_2O_3 content, a mass mean aerodynamic diameter of 2.0 ± 0.5 μm, and a particle size weight percentage of 60 ± 10 % less than 2.5 μm, as determined by the average of three Andersen impactor test runs performed with the test conditions specified in the generic verification protocol, Table 2. The impactor will utilize all five of the manufacturer designed particle size separation stages above the 2.5 µm stage. The stages that capture particles larger than 2.5 μm are used as a filter to prevent larger particles from removing smaller particles in the succeeding stages.

B4.1.3 Analytical Balances and Associated Equipment

- Low resolution analytical balance for sample filters.
- High resolution analytical balance for impactor filter stages.

B4.1.4 Calibration Weights and Associated Equipment

- Dust feed scale.
- Aluminum foil, permanent marker for labeling, tweezers, humidity- and temperature-controlled work space.
- Recovery brush.
- Continuous temperature and humidity monitor with data-logging capabilities.

B4.1.5 Impactor, Collection Substrates, and Associated Materials

- Andersen model 50-900 impactor.
- Collection substrates.
- Acetone.
- Wash bottles.

B4.1.6 Absolute Filter Assembly With Untared Filters

- Absolute filter assembly with untared filters.
- Paraffin film or Teflon tape.

Table 3. Test Apparatus Equipment

Component	Make	Model Number	Performance Capability
Optical Photo Sensor	Sick Optic Electronic	FW 56-D/T	± 0.4 %
Impactor	Andersen	50-900	
Mass Flow Controllers	Hastings Instruments	HFC-202	0 to 12 m^3/h (0 to 7.1 ft^3/m) ± 1 %
Dust Feeder	Sensor Techniques Limited	NDF 100	20 to 200 g/h (0.044 to 0.44 lb/h)
Thermocouple	In house	NiCr/Ni-Thermoelement	0 to 250 °C (32 to 482 °F)
Pressure Transducer	MKS Baratron	223B	0 to 2000 Pa (0 to 0.29 psi) ± 0.5 %
High Resolution Analytical Balance	Precisa	290 SCS	0.00001 g
Low Resolution Analytical Balance	Andy	HR200	0.0001 g
Absolute Filter	Andersen Instruments, Inc.	50-31 (0 or 2)	99.99 %
Temperature and Humidity Monitor	ACR Systems, Inc.	Smart Reader 2	-20 to 40 °C (-4 to 104 °F) ± 10 % RH
Vacuum Pump	Rietschle	VLT 15	15 m^3/h (ft^3/m)
Barometer	Princo	Nova Full Range Mercurial	636 to 838 mm Hg (25 to 33 in. Hg).

B4.1.7 Ambient Humidity and Barometric Pressure Measurement Devices

- Barometer.
- Sling psychrometer, ambient humidity measurement monitor.

B4.2 Procedures

Detailed procedures are provided in the attached SOP, Appendix C. Prior to loading the sample filter, the LTG/FEMA test apparatus must be set at a G/C of 73.1 m/hr (4.0 fpm) and a dust loading of 34.4 g/dscm (15.0 gr/dscf). The G/C and the dust loading will be determined using an untared filter that will not be used during the verification test. Before the performance evaluation test can be performed, the sample filter media must be subjected to a conditioning period consisting of 10,000 rapid pulses and a recovery period consisting of 30 pulses at normal test conditions. The sample filter and the absolute filter are loaded into the LTG/FEMA test apparatus, and a sufficient amount of test dust is placed in the dust feed hopper (see Appendix C, SOP section 3.2 for detailed dust amount requirements). Once the LTG/FEMA test apparatus has been prepared, the sample filter media will be subjected to 10,000 rapid pulses at 3-second intervals. The dust loading and the G/C will be calculated on a block average for each 60 consecutive minutes during the test and for the last 60 minutes of each test. The parameters as listed in SOP section 4.4.1 must be measured and recorded to confirm that the conditioning period requirements are maintained.

The recovery period will be a continuation of the conditioning period, except the pulse filtration frequency will be reduced to normal pulse frequency, determined by the 1,000 Pa (4.0 in. w.g) residual pressure drop. The recovery period does not have to be run immediately after the conditioning period, but the test apparatus and the sample filter must remain unchanged and untouched.

Prior to the commencement of the performance test, the dust must be replenished within the dust feed hopper (see SOP section 3.2), and the impactor must be inserted into the LTG/FEMA test apparatus. The performance test will be performed using normal pulse filtration cycles as required in the recovery period. The performance test will be run for 360 continuous minutes. The recording requirements, as listed in the attached SOP, sections 4.4.1 and 4.4.3.2, will continue to be followed during the performance test period.

The first of the three test runs of each verification test set will receive a quick check of the particle size range and dust load. The quick check will be performed using the Andersen impactor and will be carried out in conjunction with the 10,000-pulse conditioning period. If the G/C and the dust loading requirements are not maintained throughout the three test periods, the test will be voided and will be repeated using a new filter sample.

Refer to the SOP, Appendix C, for detailed step-by-step procedural directions.

B5.0 Quality Control Requirements

Data quality objectives and test specifications are shown in Tables 1 and 2, respectively. The quality control limits are specified in Table 4. The means of measuring and verifying the attainment of the data quality objective, and corrective actions that will taken if needed are discussed below for each item.

B5.1 Test Dust Particle Size Percentage and Mass Aerodynamic Diameter

The mass mean diameter and particle size distribution of the test dust will be measured quarterly (or with each new shipment). The determination will be made by the average of three Andersen impactor runs conducted on the raw-gas channel upstream of the test filter. In addition, prior to each verification test series, the test dust specification will be confirmed with a single Andersen particle size measurement, again conducted in the raw-gas channel of the test apparatus (see Appendix C, sections 4.3.3 and 4.3.4 for testing procedures).

In the event the mass mean diameter and weight percent <2.5 μm do not meet the criteria specified in Table 2, the test dust or dust feed system must be corrected and verified prior to testing.

B5.2 Filter Sample Diameter

Procedures for the filter sample preparation are detailed in Appendix C, section 4.2. The procedure for cutting the filter sample is to use the test apparatus sample clamping ring as a template for cutting. This is a go/no-go procedure, samples cut either too small or too large are unusable.

B5.3 Flow Rates (Raw Gas and Clean Gas)

Both the raw-gas and clean-gas flow meters and flow controllers will be calibrated annually as described in section B7.3. Prior to each verification test a calibration check will be conducted, also described in section B7.3 of this Test/QA Plan. If the pre-test check deviates by more than 3 percent (data quarterly limit is 5 percent), the associated flow meter must be recalibrated before proceeding with the test.

B5.4 Gas Temperature

The thermocouple is calibrated quarterly against an ASTM mercury-in-glass thermometer. The accuracy of the thermocouple sensor will be assessed prior to each test series by comparing its reading to the reference thermometer. The thermocouple must agree with the reference thermometer to within ± 1 °F.

Table 4. Data Quality Limits

Parameter	Frequency and Description	Control Limit
Test Dust Particle Size Percentage	Quarterly and each new test	± 10 %
Test Dust Mass Mean Aerodynamic Diameter	Each test series	± 0.5 μm
Filter Sample Diameter	Each test specimen	± 1.6 mm (0.063 in)
Inlet Raw-Gas Flow rate	Each test run	± 0.3 m^3/hr (0.18 ft^3/m)
Filtration Velocity	Each test run	± 3.6 m/hr (0.20 ft/m)
Gas Temperature	Raw gas temperature measured each test run	± 2.2 °C (4 °F)
Inlet Dust Concentration	Raw gas dust concentration measured each test series	± 10 %
Weight Gain of Reference Fabric	Quarterly	± 10 %
Maximum Pressure Drop (with respect to reference fabric)	Quarterly	± 10 %
Mean Outlet Particle Concentration PM 2.5 (g/dscm)	Each test run	± 15 %
Mean Outlet Particle Concentration Mass (g/dscm)	Each test run	± 15 %
Average Residual Pressure Drop Across Sample (cm w.g.)	Each test run	± 5 %
Average Filtration Cycle Time (sec.)	Each test run	± 1 %

B5.5 Inlet Dust Concentration

The dust feed weight cell is calibrated prior to each test series. The calibration is conducted by placing a 2-3 kg NIST-traceable span weight in the weigh hopper prior to each test series. In addition the dust concentration is measured in the raw gas channel. This measurement is made in conjunction with impactor tests described in section B5.1 and Appendix C, section 4.3.4.

B5.6 Weight Gain of Reference Fabric and Maximum Pressure Drop

Once each quarter the test apparatus is calibrated against the APCT supplied reference fabric employing the test dust and test conditions as used for the verification tests. The calibration procedures will comply with those described in section 2.4 of the *Generic Verification Protocol for Baghouse Filtration Products (November 1999).* Both the weight gain of the reference fabric and the maximum pressure drop recorded must fall within ± 10% of the corresponding values established by the APCT office. If the criteria are not met, all verification testing is stopped, the APCT office is notified, and corrective action is taken.

B5.7 Mean Outlet Particle Concentration (PM 2.5 and Mass)

Quality Control procedures for the calibration, inspection, and operation of the test apparatus are described in sections B5.0 - B7.0 of this Test/QA Plan. In addition, procedures for proper pre-test, test, and post-test impactor are described in Appendix C, sections 4.2 - 4.2.3, 4.4.3.1, and 4.5 - 4.5.2. If all of the above procedures are followed, the DQO of ± 15% for these parameters is achievable.

B5.8 Average Residual Pressure Drop Across the Sample

The residual pressure drop across the filter sample is measured 3 seconds after the conclusion of the cleaning pulse (once per filtration cycle). It is monitored and recorded continuously throughout the recovery and performance periods of each test. Prior to each test series the pressure transducer is checked against an oil manometer, Dwyer model 424-5, 0.1-in. minor deviation with accuracy of ± 1%.

B5.9 Average Filtration Cycle Time

The time between filtration cycles is monitored and recorded continuously throughout the recovery and performance periods of each test. The timer clock is calibrated quarterly to NIST time. If the timer clock is not within 1-second agreement with the NIST signal over a 1-hour period, the timer clock is discarded and replaced with a unit that meets the calibration requirement.

B6.0 Instrument/Equipment Testing, Inspection, Maintenance

As part of each test series, tests are performed to assess the reliability and accuracy of the test apparatus. In compliance with the BFP generic test protocol section 2.4, quarterly testing using the reference fabric is conducted to verify the accuracy of the pressure drop transducer and the dust feed rate. Prior to each test series the appropriate instrument settings necessary to achieve the test specification filtration velocity and dust feed rate are determined by physically measuring the gas flow, and calibrating and monitoring the dust-feed load cell. In addition, a dust-feed quick check consisting of a single impactor measurement is performed during the first conditioning period of each test series to confirm the concentration and dispersion of dust in the raw-gas channel. These procedures are detailed in Appendix C, Standard Operating Procedures. Should any of these checks not meet the specified criteria, testing is stopped until corrective adjustments are made and re-inspection meets the criteria.

Periodic preventive and corrective maintenance is conducted according to manufacturer's instructions on apparatus and equipment components such as the compressed air system, raw- and clean-gas pumps, and the dust feed system.

B6.1 Equipment Inspection and Maintenance

Each item of test equipment is assigned a unique, permanent identification number for tracking equipment use, maintenance, and calibration. An effective preventive maintenance program is a necessary step in ensuring quality data. Before each test series the equipment is inspected and its components are cleaned, repaired, reconditioned, and recalibrated when necessary.

Occasional equipment failure is unavoidable despite the most rigorous inspection and maintenance procedures. For this reason, ETS keeps spare equipment for critical testing components.

B7.0 Instrument Calibration and Frequency

Calibration will be performed as outlined in Table 5. In addition to these calibrations, a series of calibration checks are conducted on each instrument at least on a quarterly basis and in many cases prior to each use.

Sections B7.1 through B7.9 provide the calibration check procedure and frequency of checks for each instrument.

B7.1 High Resolution Analytical Balance

The high resolution analytical balance will be calibrated by a factory service representative on an annual basis. Prior to each use, calibrate the balance using the zero and span functions of the balance. Check each calibration using the 1 mg calibration weight plus the clean substrate and aluminum foil it is wrapped in. The tare weight of the clean substrate/aluminum foil is approximately 750 mg. Typical substrate weight gains after testing are expected to range between 1 and 4 mg. The balance should read to calibration weight to within 0.0005 g. If not, repeat the procedure or adjust the balance until the value is obtained.

B7.2 Low Resolution Analytical Balance

The low resolution analytical balance will be calibrated by a factory service representative on an annual basis. Prior to each use the calibration will be checked using the 100-g span weight. The balance should display within 0.05 g of the NIST-certified calibration weight. If not, repeat the procedure or adjust the balance until the value is obtained.

B7.3 Flow Meters and Flow Controllers

Calibrate annually according to 40 CFR 60, Appendix A, Method 5, Section 7.1.1. The calibration will be conducted at three different flow rates that bracket each instrument's normal operating range. The reference standard for the calibration will be a spirometer/bell prover or a wet test meter that has been certified in the past year. Prior to each verification test a calibration check will be used on each flow instrument. The calibration check will be conducted using the above mentioned reference method. The calibration checks will be conducted at a single point corresponding to the verification test specification air flows for each instrument. The clean-gas flow instrument will be calibrated at a flow of 0.76 ± 0.04 cfm (flow rate equivalent to a filtration velocity of 4.0 fpm). The raw-gas flow instrument will be calibrated at a flow of 2.65 ± 0.13 cfm. Each calibration will be conducted for a minimum of 10 minutes. A calibration factor will be used to adjust the measurement to that of the wet test meter. If the pretest check deviates by more than 3 %, the flow meter must be re-calibrated.

B7.4 Pressure Transducers

The pressure transducers will be calibrated annually against a reference pressure standard that has been certified against NIST-traceable standards within the past year. Prior to each test series each pressure transducer will be checked against an oil manometer to within 0.25 cm w.g. (0.1 in. w.g.). The pressure transducers will be calibrated at three points, zero, span, and at a pressure typically encountered during the verification tests.

B7.5 Barometric Pressure Transducer

The barometric pressure transducer will be calibrated prior to each test against the mercury-in-glass barometer.

B7.6 Thermocouple in Raw-Gas Channel

This thermocouple will be calibrated quarterly against an ASTM mercury-in-glass reference thermometer at 74 ± 4 °F. Alternatively, the thermocouple will be calibrated at a thermometric fixed point above and below 74 ± 4 °F (for example, use an ice bath and boiling deionized water).

B7.7 Continuous Humidity and Temperature

This instrument will be returned to the factory for annual calibration with NIST traceability.

B7.8 Timer Clock

The timer clock should be calibrated quarterly to NIST time, which is obtained from the WWV radio reference signal or from the NIST World Wide Web site, *www.boulder.nist.gov/timefreq/*. If the timer clock is not within 1-second agreement with the WWV or website signal over a 1-hour period, the timer must be replaced with a unit that meets calibration requirements.

B7.9 Dust-Feed Weight Cell

This Instrument will be calibrated prior to each test series. The calibration will be conducted with the dust-feed hopper empty, and placing a 2 kg span weight into the weigh hopper. Calibration weight must meet ASTM class 4 with a NIST/NVLAP-traceable certificate.

The above calibrations will be recorded for inclusion in the Verification Report.

Table 5. Instrument Calibrations and Frequency

Instrument	**Calib. Frequency**	**Calibration Method**
Low Resolution Analytical Balance	Annual	Factory calibration with NIST-traceable standards.
High Resolution Analytical Balance	Annual	Factory calibration with NIST-traceable standards.
Flow Meters and Flow Controllers	Annual	Method 40 CFR 60, Appendix A, Method 5, Section 7.1.1
Pressure Transducers	Annual	Against reference pressure with NIST traceability
Barometric Pressure Transducer	Prior to each use	Against mercury-in-glass barometer
Thermocouple	Quarterly	Against ASTM mercury-in-glass reference thermometer
Continuous Humidity and Temperature	Annual	Factory calibration with NIST traceability
Timer Clock	Quarterly	Calibrate to NIST time
Dust Feed Weight Cell	Prior to each test series	NIST certified span weights

B8.0 Inspection/Acceptance Requirements for Supplies

The sample custodian will receive reference filter media from the APCT Program Manager. The APCT Program Manager will include a letter attesting that the fabric is identical to the components that were identified in the generic verification protocol. The ETS sample custodian is responsible for maintaining an adequate supply of all other consumable products, including but not limited to, reference dust, absolute filters, impactor substrate filters, and acetone. The sample custodian will verify the manufacturer's information (type, model number, style, etc.,) for consistency and correctness. A supplies log and a chain-of-custody record will be filled out and the correspondence from the APCT Program Manager and other manufacturers will be marked accepted and retained on file.

B9.0 Data Acquisition Requirements (Non-Direct Measurements)

Any data or reference source that is required while determining the verification parameters or compiling the Verification Report, that is not a measured value, will be disclosed within the Verification Report. The reference will include all pertinent information, including the reference source title, section, and important information taken. This requirement includes databases that might be used, programs, literature, and files. All existing data must meet the same quality assurance requirements as are applicable to data generated during the verification tests and must be generated independently from the sample media manufacturer as stated in the ETV quality manual, Appendix C.

B10.0 Data Management

Interim stages of data review and validation will be provided for several key points in the process to minimize revisions if corrections or changes are needed.

Test data will be input into computer spreadsheets each day following testing. Results of sample analysis will be input into the computer system upon receipt from analytical laboratories. Process data will consist of logs and continuously monitored data. Data will be reduced and analyzed using computer spreadsheets.

B10.1 Data Flow

All testing, data generation, and data analysis are performed within the ETS building. All data is acquired in real time. The following shows the flow of data from its origin in the test laboratory to final storage.

A. Data origination in test laboratory:

Data generated by the LTG/FEMA apparatus:

- Read in real time by a data acquisition computer located at the test rig.
    - · Temperature.
    - · Air flow, raw gas, and filtration velocity.
    - · Filtration cycle time.
    - · Residual pressure drop.
    - · Maximum test pressure drop [1,000 Pa (4.0 in. w.g)].
    - · Dust feed rate.
    - · Dust feed concentration stability (photometer)
- Hard copy printout of each sample printed in real time.

Data generated manually or by observations:

- Readings are recorded manually on a test run sheet.
    - · Relative humidity.
    - · Atmospheric pressure.
    - · Impactor sample flow rate.
    - · Impactor weight gains.
    - · Filter specimen weight gain.

B. Inspection of LTG/FEMA data for acceptance at the test site:

After each verification test, the data from the LTG/FEMA data acquisition computer are transferred to a diskette labeled with the corresponding test number.

The diskette is installed into another computer located in a nearby area of the data acquisition computer. The LTG/FEMA data from the diskette are loaded into a spreadsheet program template. The spreadsheet program computes the sample's outlet particle concentrations, and checks the DQOs associated with outlet particle concentration data.

The spreadsheet program is saved to a diskette using the designated test number.

C. Spreadsheets:

Two spreadsheets are used in the program. A data analysis spreadsheet is used to analyze the data from each individual run. A data summary spreadsheet is used to combine the results from the triplicate tests and their associated control tests, and to compute outlet particle concentrations. Further details pertaining to the spreadsheets, spreadsheet equations, and example spreadsheets are located in the attached SOP, Appendix B.

D. Draft Report Preparation:

The diskette and the test run sheets are delivered to the Report Manager. The Report Manager inspects the test run sheets for completeness; if there are any omissions, the Report Manager immediately follows up with the Test-Specific Team Leader to fill in any missing information.

Following the formats for the verification statement and report, as specified in the generic verification protocol, the Report Manager prepares these documents.

The Report Manager will inspect all results for reasonableness and correctness relative to test number, date and times of samples, and sample identification.

The Report Manager will maintain the diskette in an appropriate storage area as specified in Section A9.2.1.

E. Long-term Storage:

The original copy of all verification test data, calibration data, certificates of calibration, assessment reports, verification reports, and verification statements will be retained by ETS for a period of not less than 7 years after the final payment of the assistance agreement as per Part A, Section 5.3 of the ETV QMP. A duplicate copy will be sent to the APCT Program Office for storage.

B11.0 Reporting

Upon completion of testing, the Report Manager will be responsible for compiling the data summary into a Verification Report. The results of the test program will be evaluated for completeness and representativeness and will include all valid data collected. The report will be submitted in electronic and hard-copy form to the APCT Program Manager within 30 days after completion of sampling for approval. Data and results interpretations will be presented as necessary in the report. The report will contain all items specified in Section 4.0 of the generic verification protocol including but not limited to the following sections:

A: Title Page. The title page includes the client's name, ETS' laboratory information, the client's location and company information, and the date(s) on which the testing was conducted.

B: Table of Contents. The table of contents contains an outline of the test report and page numbers on which the sections appear.

C: Figures & Table. The figures and tables page contains a listing of all figures and tables located throughout the report including corresponding page numbers.

D: List of Abbreviations & Acronyms. A list of all acronyms and abbreviations located throughout report and their definitions.

E: Introduction. The introduction includes a background statement addressing sampling purpose, sampling type, sample manufacturer, and date(s) of testing. Also included is a Test Matrix table that outlines the testing program, indicates the date(s) of testing, provides the testing objectives and methods used throughout the entire testing series, and provides appropriate run numbers for each test. In addition, a list of participants is presented that indicates all persons from ETS present during the testing.

F: Technology Description. Technology description section describes the principles of operation for the test equipment, the history of the test equipment, the advantages and limitations of the test equipment, and any performance characteristics that affect the testing.

G: Sampling and Analytical Procedures. This section indicates the sampling and analytical methods used and their applicability to the testing performed. Sampling data and results, raw data, and laboratory data are referenced to their appropriate sections in the Appendix.

H: Results & Evaluations. The summary of results section presents a summary and comparison of verification parameters and critical measurements determined from the testing performed. This section also includes a summary of laboratory QA/QC characteristics.

I: Observations & Discussion of Results. This section contains a discussion of any conclusions that may have been determined from the testing, if applicable. Any sampling or analytical problems encountered during the test program are also discussed in this section.

J: References. The reference section includes all material and author information that was used or cited during testing and report procedures.

K: Appendices.

APPENDIX A - Test Log

APPENDIX B - Raw Test Data and Laboratory Data
APPENDIX C - Calculations
APPENDIX D - Equipment Calibrations and QA/QC Support

PART C ASSESSMENT/OVERSIGHT

C1.0 Assessments and Response Actions

The Test-Specific QAO may elect to perform a self-assessment during the first round of BFP testing. APCT and/or EPA quality assurance staff will perform an independent assessment, two TSAs, and one PE, during Round 1 of the BFP verification tests to determine that the DQOs are met. The Test-Specific QAO will conduct an ADQ for 10 % of all verification test data at the end of each round of the verification tests and will determine if these measurements allow one to determine if the DQOs have been attained. These technical assessments will be performed in accordance with *EPA Guidance for Technical Assessments for Environmental Data Operations*(EPA QA/G-7).

The Test-Specific QAO will report the findings of these technical assessments to the Verification Test Leader with copies sent to the EPA Project Manager and to the ETS task leader. The assessment report will recommend corrective actions, if such are indicated by these findings. The Verification Test Leader and the Test-Specific QAO are responsible for developing, documenting, and implementing corrective actions. They will provide a written response to all assessment findings. Each finding will be addressed with specific corrective action steps and a schedule to implement them. Responses to adverse findings are required within 10 working days of receiving the assessment report in accordance with the requirements of Part B, Section 4.3 of EPA's Quality and Management Plan for the Environmental Technology Program. The RTI Program Manager will review and approve all corrective actions.

Technical assessments and corrective actions are described in detail in Sections 3.4 and 3.5 of the APCT QMP.

Technical personnel working on each task will have the direct responsibility for ensuring that the Test/QA plan is implemented, that the operating parameters are within acceptable limits, and that corrective actions are taken when appropriate. Corrective action will be taken whenever measurements fall outside the limits of the data quality objectives for the critical measurements.

Corrective actions include:

- Problem identification,
- Attempting to find the cause,
- Attempting immediate repairs (if possible),
- Reporting or documenting the problem,
- Planning for corrective action (if major repairs are needed),
- Documenting the corrective actions taken, and
- Recommending changes to instruments, SOPs, etc. to avoid similar future occurrences.

ETS will cooperate with EPA on scheduling EPA's assessments on this program.

C2.0 Reports to Management

The Test-Specific Manager will notify the Verification Test Leader and the Test-Specific QAO when testing under this project is being conducted. The Test-Specific Manager will submit verification reports and verification statements to the Test-Specific QAO. After technical assessments, the Test-Specific QAO will submit the assessment reports, verification reports, and verification statements to the Verification Test Leader. The Verification Test Leader will submit the reports, statements, and assessment reports to the APCT Program Office for review. After review is complete, the APCT Program Office will submit the verification reports and the verification statements to the EPA Project Manager for review and will submit assessment reports to the EPA Project Manager for informational purposes.

PART D DATA VALIDATION AND USABILITY

D1.0 Data Review, Validation, and Verification Requirements

Data quality audits will be conducted using data quality indicators that require the detailed review of: (1) the recording and transfer of raw data; (2) data calculations; (3) the documentation of procedures; and (4) the selection of appropriate data quality indicators. The data quality indicators that will be used are as follows:

- Use of correct test conditions, as specified in Table 2, for the LTG/FEMA apparatus.
- Adherence to calibration schedule.
- DQOs attained as specified in Appendix A..
- Adherence to standard operating procedures.

All data and/or calculations for flow rates, dust feed rates, moisture content, isokinetic rates, and particle concentrations and mass rates made using a computer software program will be validated by an independent check. All calculations will be spot checked for accuracy and completeness.

In general, all measurement data will be validated based on the following criteria:

- Process conditions are at the required conditions during testing.
- Sample collection procedures are performed as required by SOP.
- Data are consistent with expected results.
- Sampling procedures adhere to prescribed QC procedures.

Any suspect data will be flagged and identified according to the specific deviation from prescribed criteria and their potential effect on the data quality.

All QA/QC results will be reviewed before the data are released; any data that fail to meet the program's QA/QC requirements will be documented and discussed.

D2.0 Data Transformation and Reduction

Standardized forms will be used to record data for each test method. These forms are provided as attachment B to the SOP. All run sheets are to be reviewed daily by the Test-Specific Team Leader for evaluation of progress, completeness, and nonconforming items. Standardized computer spreadsheets will be used to reduce and analyze data. At the end of each test day, test data will be input into these spreadsheets. Laboratory analytical results may not be available at the end of each test day; however, results will be input as they become available. A standard data set that has been verified by hand will be used to demonstrate the accuracy of the spreadsheet calculations before and after the test program. Example spreadsheets and run sheets can be found in the attached Appendices B and C.

D3.0 Validation and Verification Methods

Data validation is a systematic procedure of reviewing data against a set of established criteria to provide a level of assurance of the data's validity prior to their use. Data will be validated internally by QC personnel. All measurement data will be validated based upon process conditions during sampling or testing, acceptable sample collection/testing procedures, consistency with expected and/or other results, adherence to prescribed QC procedures, and the specific acceptance criteria. The data will be coded as valid or invalid based on their adherence to these criteria. Data validation will be conducted at several critical stages of data reduction:

- Checks of raw and reduced data by the Test-Specific Manager;
- Analytical laboratory QC checks by the Test-Specific QAO;
- Spot checks of reduced raw data by the Test-Specific QAO;
- Review of summary tables for consistency with reduced raw data by the Test-Specific QAO; and
- Final report review by the Test-Specific QAO, Verification Test Leader, and Test-Specific manager.

Data validation consists of verification of calculation methodology, consistency of raw, reduced, and summarized data tables, comparison of expected results, and consistency of results among multiple measurements.

Data will be initially validated by the Test-Specific Manager based on the representativeness of the sample, maintenance and cleanliness of sampling equipment, and adherence to the sample collection procedures. The data will also be validated on a daily basis based on process conditions during sampling and adherence to acceptable criteria.

When the data set is complete, the ETS QA personnel will perform an overall review of the data. The review will consider the above listed criteria and the reasonableness and consistency of the data based on a knowledge of the site characteristics and the specific location of the samples. The review will also contain an evaluation of the data in terms of meeting the quality assurance objectives of the program. The acceptance or rejection of the data will be in a uniform and consistent manner based on the established validation criteria. Data will be rejected only if a valid and documentable reason is identified.

Validation of spreadsheet calculations used for data reduction will be conducted by entering a QA data set that has been verified by hand. Data flags will be added to all tables to identify special handling procedures or unusual data results. These flags will include:

- Quantities including analytical results that are at or below method minimum detection limits;
- Results for which contamination is suspected;
- Average results that exclude individual test run results; and
- Other special handling procedures or qualifications.

The purpose of validation and verification is to assess the degree to which the data meet the quality specifications outlined in the generic verification protocol and this Test/QA Plan. If deviations are noted, the validation procedures can be used to assess the effect the deviation will have on data usability.

The first step in data validation and verification is to assess that the project, as executed, meets the sampling design. Specific steps are listed below:

- Process data will be reviewed to ensure that the unit was operating within the limits outlined in the project.
- Test dates and times will be reviewed to ensure that testing was performed as scheduled and checked against the project design.
- The methods performed and the reference dust will be checked against the project design.
- Actual procedures documented in the test logs and on test data sheets will be checked against the procedures described in this Test/QA Plan and the SOP.
- Deviations from the Test/QA Plan will be documented.
- Sample custody and preservation will be checked for each sample component against the Test/QA Plan.
- The analytical procedures performed during the test program will be checked against those described in this Test/QA Plan.

Any deviations will be documented in the report. The review of quality control data such as duplicate sampling data and sampling verification checks can be used to validate test collection activities. The review of data from calibration checks, reference media test runs, and other quality control can be used to validate the analytical process. Acceptable precision and bias in these samples would lead one to conclude that the analytical procedures are adequate. Any data that indicate unacceptable levels of bias or precision will be flagged and investigated. This investigation could lead to the discovery of inappropriate sampling activities or analytical procedures, requiring corrective action.

Validation of QC procedures will require a review of the documentation of corrective actions that were taken when QC samples failed to meet acceptance criteria, and the potential effect of corrective actions on the validity of the data.

Validation of data reduction and processing procedures will require selection of 10 % of the data chosen at random. Raw data files including pre-sampling, sampling, calibration, sample handling/custody, analysis, corrective action, and data reduction will be reviewed and sample calculations will be performed. The data will also be reviewed to ensure that data qualifiers have been appropriately associated with the data and appropriate corrective actions have been taken where needed.

All data will follow a chain-of-custody containing checks at each level. The chain-of-custody for all test data collected will be as follows:

1) The testing technicians collect the data on standardized data sheets.

2) These data sheets are given to the Test-Specific Leader who performs an on-site review.

3) The Test-Specific Leader presents the test data package to the Report Manager, who performs an additional review and prepares the draft Verification Report and draft Verification Statement.

4) The draft Verification Report and the draft Verification Statement, including the test data, are given back to the Test-Specific Leader for review.

5) The draft Verification Report and draft Verification Statement, including the test data, are given to the Test-Specific Manager for review.

6) The draft Verification Report and draft Verification Statement, including the test data, are given to the Test-Specific QA Officer for review.

7) The draft Verification Report and draft Verification Statement are sent to the APCT Program Office for review.

8) The draft Verification Report and draft Verification Statement are sent to the EPA for review, approval, and signature.

During review of the verification report and verification statement, a Document Control and Review form shall be maintained to track operational review and document custody.

D4.0 Reconciliation with Data Quality Objectives

ETS will complete a Reconciliation of Verification Test Results with Data Quality Objectives form during the verification test series to record if the test results attain the DQOs. Using the results obtained from the project and the comparison with quality assurance objectives, ETS will investigate to identify any abnormal pattern or potential anomalies. ETS and APCT quality assurance staff will have the final evaluation as to whether or not the project met the objectives of the sampling design, and whether or not departures, if any, from QA/QC guidelines are significant and acceptable. The conclusions will be presented in the verification report.

Quality objectives for this project were designed to evaluate various phases (sampling, preparation, analysis) of the measurement process to ensure that total measurement uncertainty is within the range prescribed by the DQOs in Section A7.0. More specifically, the quality objectives were defined in terms of the following data quality indicators:

- Accuracy,
- Precision, and
- Completeness.

D4.1 Accuracy

Accuracy results obtained during the test program will be checked against accuracy criteria in Section A7.2 *Measurement Performance Criteria*. If data do not meet the accuracy quality objectives, ETS will conduct an investigation to uncover and explain the cause.

Accuracy is defined as the agreement between a measurement and the actual (i.e., true) value. For example, accuracy of an analytical measurement is expressed as the percent recovery of an sample at a known concentration prior to analysis, and is expressed by the following formula:

$$Accuracy = \%\,Recovery = \frac{A_T - A_O}{A_F}\,x\,100$$

Where:

A_T = Total amount found in known concentration or standard
A_o = Amount found in sample, and
A_F = Amount added to sample**.**

D4.2 Precision

In this project, precision will be determined for air samples based on results for triplicate samples in terms of relative standard deviation (RSD). Using the RSD of triplicate samples collected (three sampling runs) and analyzed will provide an evaluation of the overall sampling and analysis precision. Precision results obtained during the test program will be checked against precision criteria in Section A7.2 *Measurement Performance Criteria*. If data do not meet the precision quality objectives, an investigation will be conducted to uncover and explain the cause.

Precision is defined in *EPA Requirements for Quality Assurance Project Plans for Environmental Data Operations, EPA QA/R-5,* as the measure of mutual agreement among individual measurements of the same property, usually under prescribed similar conditions expressed generally in terms of analysis of samples relative to the average of those results for a given sample using the formula:

$$\%\,RSD = \frac{\sigma}{\mathrm{X}}\,x\,100$$

Where:

%RSD = Relative standard deviation,
σ = Standard deviation of the triplicate sample results, and
$\bar{X}$ = Average of the triplicate results.

D4.3 Completeness

In this project, completeness is measured by the amount of valid data obtained from the measurement system compared to the amount that was expected to be obtained under correct, normal conditions. Completeness results obtained during the test program will be compared to completeness criteria in Section A7.2 *Measurement Performance Criteria*. If data do not meet the completeness quality objectives, an investigation will be conducted to uncover and explain the cause.

Completeness is a measure of the relative number of analytical data points that meet all of the acceptance criteria for accuracy, precision, and any other criteria required by the specific analytical methods used. The level of completeness can also be affected by loss or breakage of samples during transport, as well as external problems that prohibit collection of the sample.

As part of the data verification and validation process, these data quality indicators will be calculated and compared to data quality objectives for the program. The final test report will address whether or not objectives were met and, if not, the impact on the final data will be determined.

D5.0 Corrective Action Procedures

The following occurrences will require corrective action:

1. QA Goals Not Achieved: This occurrence includes failure to achieve the specified accuracy and completeness criteria.

2. Audit Deficiencies: Two types of audits will be conducted in this program. Internal audits are conducted by the Test-Specific QAO, and external audits are conducted by the RTI QA staff. Deficiencies may be identified during systems and/or performance audits.

It is the responsibility of the Test-Specific QAO to bring to the attention of the Verification Test Leader any of the problems listed above. The Test-Specific Manager, Test-Specific QAO, and Verification Test Leader will then review and compare the QA and program goals to determine if the specific QA problem will actually cause a problem in achieving the program goals. If it is determined that the QA goals are too stringent, they will be modified (with approval of the APCT Quality Manager) to reflect the current program objectives.

If the QA and program goals are determined to be satisfactory, the Verification Test Leader will review the subject measurement systems and procedures. The Verification Test Leader will proceed to solve measurement system problems as required. When the Verification Test Leader has determined that the problems have been solved, the Test-Specific Manager and the Test-Specific QAO will verify the results. This process may include specific calibration, and systems and/or performance audits. Any remaining problems will be resolved by the Verification Test Leader.

APPENDIX A

Attaining the Quality Objectives for the Mean Outlet Particle Concentration (PM 2.5 or total)

Let $\boldsymbol{\varepsilon}_x \equiv$ error in x, and

Mean Outlet Particle Concentration $\equiv$ MOPC = 1/3 $[\sum(C_{po})_i]$

where C_{po} = a single measurement of the concentration and

i = 1,2,3 (triplicate runs)

Quality objective for $\boldsymbol{\varepsilon_{MOPC}} \leq$ 15 % for triplicate runs.

1. Apportion Total MOPC error as:

$$\varepsilon_{MOPC}^2 = \varepsilon_{Bias}^2 + \varepsilon_{Random}^2 \leq (15\ \%)^2$$

$\varepsilon_{Bias} \leq 10$ % (maximum allowable deviation from reference fabric results – a range)

$$(0.1)^2 + (\varepsilon_{Random}/3)^2 \leq (0.15)^2 \Rightarrow \varepsilon_{Random}^2 \leq 3x[(0.15)^2 - (0.1)^2] = 0.0375$$

$$\varepsilon_{Random} \leq 0.19 = 19\ \%$$

i.e., total random error in each measurement of the outlet particle concentration must be held to 19 % or lower in order to attain the quality objective.

2. Each measurement of Outlet Particle Concentration (C_{po}):

$C_{po} = D_{mass}/V_{Outlet}$

where:

$$\begin{aligned} D_{mass} &= \sum[(\text{Substrate Mass})_{Final} - (\text{Substrate Mass})_{Initial}] \text{ for impactor stages,} \\ &= [(Mass1_{Final} \pm \varepsilon_{Mass}) - (Mass1_{Initial} \pm \varepsilon_{Mass}) + \\ &\quad (Mass2_{Final} \pm \varepsilon_{Mass}) - (Mass2_{Initial} \pm \varepsilon_{Mass}) + \\ &\quad (Mass3_{Final} \pm \varepsilon_{Mass}) - (Mass3_{Initial} \pm \varepsilon_{Mass}) + ...] \\ &= [(Mass1_{Final}-Mass1_{Initial}) + (Mass2_{Final}-Mass2_{Initial}) + ... + \sum(\varepsilon_{Mass})] \end{aligned}$$

where ε_{Mass} = measurement error in each handling and weighting of each substrate.

V_{outlet} = Sampled Volume = $(\text{Flowrate})_{Outlet}$ x (Sampling Time)

where $\varepsilon_{Flowrate} >> \varepsilon_{SamplingTime}$

$V_{outlet} = V_{imp}$ ... since the full volume of the clean gas is drawn through the impactor.

Then $(\sigma_C/C)^2 = (\sigma_D/D)^2 + (\sigma_V/V_{imp})^2$;

$= 2x5[0.00005/0.002]^2 + [0.06/7.8]^2 = 0.0063$

where it is assumed that the cumulative substrate mass gain is uniformly distributed over all five stages (0.01g/5stages = 0.002g/stage).

σ_C/C = 8 % less than ε_{Random} < 19 %

where

	Value	Source
σ_D	0.00005 g	Table 1
n	5	number of impactor stages cutting < 2.5 μm
D	0.01 g	minimum cumulative substrate mass gain
C	0.3 g/dscm	99 % removal efficiency of inlet concentration of 35 g/dscm
σ_V	0.06 m^3/h	Table 1
V_{imp}	7.8 m^3	taken from initial shakedown test, 6-hour duration

APPENDIX B

Sample Chain-of-Custody Record, Label, Record of Consumables, Inspection/Acceptance Testing Requirements, and Log for Tracking Supplies and Consumables

Contents

Example
Chain-of-Custody Filter Media Samples

Station Location	Date	Time	Sample Manufacturer	Sample ID Number	No. of Samples	Responsible Individual
Receiving	10-17-99	4:20 pm	BASF	99-577BFP3-A	9	TW
Selection and Preparation	10-25-99	09:00 am	BASF	99-577BFP3-A	9	TW
Pre-test Weighing	10-25-99	09:00 am	BASF	99-577BFP3-A	3	FC
Testing	10-26-99	08:00 am	BASF	99-577BFP3-A	1	AH
	10-27-99	08:00 am	BASF	99-577BFP3-A	1	AH
	10-28-99	08:00 am	BASF	99-577BFP3-A	1	AH
Post-test Weighing	10-27-99	10:00 am	BASF	99-577BFP3-A	1	FC
	10-28-99	10:00 am	BASF	99-577BFP3-A	1	FC
	10-29-99	10:00 am	BASF	99-577BFP3-A	1	FC
Storage	10-25-99	11:00 am	BASF	99-577BFP3-A	9	TW
	10-28-99	11:00 am	BASF	99-577BFP3-A	1	TW
	10-29-99	11:00 am	BASF	99-577BFP3-A	1	TW
	10-30-99	11:00 am	BASF	99-577BFP3-A	1	TW

Example
Sample Label

Manufacturer	
Contract No.	
Test Method	
Sample ID No.	
Type of Media	

Example
Record for Consumables

Unique Identification No.	
Date Received	
Date Opened	
Date Tested	
Date to be Retested	
Expiration Date (If Applicable)	

Example
Inspection/Acceptance Testing Requirements

Critical Supplies and Consumables	Inspection/ Acceptance Testing Requirements	Acceptance Criteria	Testing Method	Frequency	Responsible Individual	Handling/Storage Conditions

Example
Log for Tracking Supplies and Consumables

Critical Supplies and Consumables (Type, ID No.)	Date Received	Meets Inspection/ Acceptance Criteria (Y/N, Include Date)	Requires Retesting (Y/N, If yes, Include Date)	Expiration Date	Comments	Responsible Individual

APPENDIX C

Standard Operating Procedures for Verification Testing of Baghouse Filtration Products Using LTG/FEMA Test Apparatus (December, 1999)

STANDARD OPERATING PROCEDURES FOR ETV VERIFICATION TESTING OF BAGHOUSE FILTRATION PRODUCTS

December, 1999

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Roanoke, VA 24012
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540-265-0131 fax

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Pollution Control Consultants
Specializing In
Toxic Emission Measurement and Control

Contents

1.0 Principle and Applicability

1.1 Principle

A fabric filter sample is subjected to a dust loading under simulated baghouse conditions using a LTG/FEMA test apparatus, which is modified from the Verein Deutscher Ingenieure (VDI) Method 3926 test apparatus. The performance of the fabric is determined relative to the following verification parameters:

- Outlet particle concentration, PM 2.5 (gr/dscf),
- Outlet particle concentration, total mass (gr/dscf),
- Average residual pressure drop (3 seconds after cleaning),
- Average filtration cycle time (time required to reach a specified pressure drop after cleaning), and
- Mass gain of test sample filter at test completion.

1.2 Applicability

This method is applicable for the determination of the above verification parameters for flat baghouse filtration fabrics. Geometric fabric configurations, such as pleated or star bags and mechanical characteristics such as seams, snap bands, and bag-to-tube-sheet fit cannot be tested using this procedure. If a filter structure other than flat swatches is to be tested, the vendor/manufacturer needs to work with ETS to propose a modification for the test apparatus that is acceptable to EPA/APCT and meets all aspects of the data quality objectives identified in the generic verification protocol.

2.0 Definitions

2.1 Conditioning Period

The period during which the fabric sample is conditioned within the test apparatus by subjecting it to 10,000 pulses at 3 seconds between pulses. Thus, the conditioning period should require 8 hours and 20 minutes for completion. Use a dust load during the conditioning period of 34.4 ± 3.4 g/dscm (15.0 ± 1.5 gr/dscf) as specified in the generic verification protocol and Test/QA Plan.

2.2 Dust Shipment

All test dust received in the same shipment and having the same lot number.

2.3 Gas-to-Cloth Ratio

The filtration velocity of the gas stream entering the test fabric in feet per minute as determined by the flow measured in the clean-gas channel (in cubic feet per minute) divided by the exposed surface area of the fabric (in cubic feet). The verification test shall maintain a G/C of 1,000 Pa (4.0 in. w.g).

2.4 Residual Pressure Drop

The pressure drop across the fabric sample contained in the test apparatus 3 seconds after a specified cleaning pulse.

2.5 Fabric Recovery Period

A time period following the conditioning period during which the fabric is allowed to recover from rapid pulsing. The fabric recovery period requires 30 filtration cycles under normal test conditions. Use a grain loading during the fabric recovery period of 34.4 ± 3.4 g/dscm (15.0 ± 1.5 gr/dscf).

2.6 Filtration Cycle

The time period between two consecutive cleaning cycles or pulses during testing.

2.7 Filtration Cycle Time

The duration or time defined by one filtration cycle.

2.8 Performance Test Period

A 360-minute test period following the fabric recovery period during which the verification testing is performed. Pulsing shall occur at a differential pressure of 1,000 Pa (4.0 in. w.g). Use a grain loading during the conditioning period of 34.4 ± 3.4 g/dscm (15.0 ± 1.5 gr/dscf).

2.9 Test Phase

The particular phase of a test run consisting of the conditioning period, fabric recovery period, or performance test period.

2.10 Test Run

The sum of three test phases including the conditioning period, fabric recovery period, and performance test period.

2.11 Test Series

Three test runs performed in series.

3.0 Materials and Apparatus

3.1 Test Apparatus and Materials

3.1.1 Test Apparatus: The test apparatus complies with the specifications that are stated in the *Generic Verification Protocol for the Baghouse Filtration Products*, which consists of the following components.

3.1.1.1 Electronic Datalogger or Programmable Logic Controller: With the ability to record residual pressure drop and filtration cycle time for each filtration cycle during the performance test period and the ability to record dust feed weight, raw-gas flowrate, and clean-gas flowrate on a 1-minute average.

3.1.1.2 Dust Feed Weight Measurement Device: A scale beneath the entire dust feed mechanism including the dust hopper with a continuous readout capable of measurement to the nearest 10 g.

3.1.1.3 Dust Feed Hopper: A dust feed hopper with a minimum capacity of 2.0 kg of aluminum oxide.

3.1.1.4 Thermocouple: Located in the high-dust channel upstream of the filter sample. This temperature can be assumed constant throughout the test apparatus.

3.1.1.5 Static Pressure Measurement Capability: The capability to measure and record the static pressure (relative to ambient) in the raw-gas channel in addition to the pressure drop across the filter sample.

3.1.1.6 Removable Clean-Gas Channel: The cylindrical clean-gas channel behind the test filter shall be constructed to allow for cleaning as specified in Section 4.2.4.4.
3.1.1.7 Manual Pulsing Function: The test apparatus must be configured to allow for manual pulsing when the dust feeder and the air compressor are not in operation.

3.2 Test Dust

Aluminum oxide (calcined alumina), AlcoaA-152SG or equivalent, having an Al_2O_3 content of greater than 99.6 %. The test dust must meet the following specifications as determined by the procedures of Section 4.3.3:

Mass mean diameter:	2.0 ± 0.5 *u*m
Weight percent < 2.5 *u*m:	60 ± 10 %

At a dust feed rate of 34.4 g/dscm (15.0 gr/dscf), approximately 206 g/hr of test dust is required in the test apparatus. A conditioning period of 10,000 pulses at 3 seconds per pulse requires a duration of 8 hours and 20 minutes for a total estimated dust feed of approximately 1,720 g. The fabric recovery period of 30 pulses may require up to 90 minutes for an estimated dust feed of approximately 309 g. Likewise, the performance test period of 6 hours requires an estimated dust feed of approximately 1,240 g. Allow at least an additional 10 % of dust to account for variations in test conditions.

3.3 Analytical Balances and Associated Equipment

3.3.1 Low-Resolution Analytical Balance for Sample Filters: Capable of measurement to within 0.01 g.
3.3.2 High-Resolution Analytical Balance for Impactor Substrates: Capable of measurement to 0.00001 g. The balance must be equipped with a draft shield enclosure and an anti-static device within the enclosure.
3.3.3 Calibration Weights:
3.3.3.1 Dust Feed Scale: 2 kg span weight. Calibration weights must meet ASTM Class 4 with a NIST/NVLAP-Traceable Certificate.
3.3.3.2 Low-Resolution Analytical Balance: 100 g span weight. Calibration weights must meet ASTM Class 4 with a NIST/NVLAP-Traceable Certificate.
3.3.3.3 High-Resolution Analytical Balance: 1 mg daily-check weight and 50 g span weight for calibration. Calibration weight must meet ASTM Class 1 standards with NIST/NVLAP-Traceable certification.
3.3.4 Aluminum Foil.
3.3.5 Permanent Marker for Labeling.
3.3.6 Single Thickness Class 100 Wipes: Crew 33330 by Kimberly-Clark, or equivalent.
3.3.7 Tweezers.
3.3.8 Recovery Brush: Suitable for recovery of loose dust from the impactor plates.
3.3.9 Humidity- and Temperature-Controlled Work Space.
3.3.10 Continuous Temperature and Humidity Monitor with Data-Logging Capabilities: Smart Reader 2 - Temperature & Relative Humidity Logger by ACR Systems, Inc., or equivalent.

3.4 Impactor, Collection Substrates, and Associated Materials

3.4.1 Andersen Model 50-900 Impactor or Equivalent: Capable of capturing total particulate matter and measuring particulate matter having a mean aerodynamic diameter of 2.5 *u*m.

3.4.2 Collection Substrates: Glass fiber substrates and backup filter. Andersen Instruments Incorporated Product Number 50-31(0 or 2) or equivalent.
3.4.3 Acetone: Reagent grade, ≤ 0.001 % residue in glass bottles.
3.4.4 Wash Bottle: Polyethylene or glass for use in the acetone rinsing of impactor components only. Do not store acetone in the wash bottles.
3.4.5 Paraffin Film or Teflon Tape: For sealing the impactor after assembly and when not in use.

3.5 Absolute Filter Assembly With Untared Filters

As specified in VDI Method 3926, suitable to protect the clean-gas flow measurement device and pump. The filters used in this assembly are not required to be subjected to the handling procedures of Section 4.2.2, as they are not subject to gravimetric analysis. The tester may choose to use these filters for analysis, in which case the procedures of Section 4.2.2 are recommended.

3.6 Ambient Humidity and Barometric Pressure Measurement Devices

3.6.1 Barometer: Capable of reading atmospheric pressure to within 2.5 mm (0.1 in.) Hg. In many cases the barometric pressure may be obtained from a nearby National Weather Service station, in which case the tester must subtract 2.5 mm (0.1 in.) Hg per 100 feet of elevation increase. [Add 2.5 mm (0.1 in.) Hg per 100 ft of elevation decrease.]
3.6.2 Sling Psychrometer or Ambient Humidity Measurement Monitor: Capable of measuring ambient humidity to within 1 % relative humidity.

4.0 Procedure

4.1 Pretest Preparation

4.1.1 Data Recording: Prepare data sheets for each test series as shown in Attachment B. All raw data shall be recorded on the data sheets for inclusion in the Verification Report.

4.2 Sample Filter Preparation

4.2.1 Selection: From the nine samples that were received from the manufacturer, randomly choose three sample fabrics.
4.2.1.1 Cutting: Use the clamping ring (see VDI Method 3926, Figure 2b) as a template. Cut at least one sample filter from each of the randomly chosen sample fabrics. Additional sample filters are recommended in preparation for voided test runs. The outer diameter of the sample shall match that of the clamping ring when laid flat. Make sure that the sample filter is homogeneous and free from seams or imperfections.
4.2.1.2 Handling: The sample filter shall be weighed and transported with a labeled, sealable, lightweight container such as aluminum foil or a plastic Ziploc™ bag or equivalent. The container is necessary to capture any loose dust from the filter after testing is completed.
4.2.1.3 Pre-Weighing: Weigh the sample filter and container to the nearest 0.01 g.
4.2.2 Impactor Substrate Preparation:
4.2.2.1 Weigh Foils: Cut aluminum foil into sections of at least 6 x 3 in. sufficient to completely contain an impactor filter and any loose dust captured on the filter. Label each foil to match its corresponding filter with a permanent marker that will not rub off during handling.

4.2.2.2. Conditioning: The impactor filters and weigh foils must be equilibrated to a constant temperature between 18 and 25 ºC (64 and 77ºF) and relative humidity of 40-60 % for at least 24 hours prior to weighing.

(1) Place each filter and its corresponding foil in an open petri dish with the foil unfolded and filter open to the atmosphere.

(2) Arrange the petri dishes on a clean tray or surface. Cover the petri dishes with dust-free wipes or dust-free boxes with one side open to atmosphere.

(3) Allow the filters, foils, and petri dishes to equilibrate for 24 hours constant temperature between 18 and 25 ºC (64 and 77ºF) and relative humidity of 40-60 %. The temperature and relative humidity must be continuously measured and recorded. Use a Smart Reader 2 - Temperature & Relative Humidity Logger by ACR Systems, Inc., or equivalent for this purpose.

4.2.2.3 Pre-Weighing: Maintain the temperature between 18 and 25 ºC (64 and 77ºF) and relative humidity at 40-60 % during weighing. Prior to each weighing, and every hour during extended weighings, calibrate the balance using the zero and span functions of the balance. Check each calibration using the 1 g calibration weight. The balance shall read the calibration weight to within 0.00005 g. If not, repeat the calibration procedure or adjust the balance. Weigh the filters within the weigh foils.

4.2.2.4 Handling: Keep the filters and weigh foils in a closed petri dish to cover and protect the filter and weigh foil during handling. After conditioning, always handle the filters and weigh foils with tweezers. The filters and weigh foils shall not contact any surface except the clean petri dish, tweezers, and the impactor during handling.

4.2.3 Impactor Preparation: Prior to each use:

(1) Rinse all internal surfaces of the impactor including the cone, body, plate holder, and all plates, gaskets, and separators that will contain substrates with acetone.

(2) Dry these surfaces with single-thickness Class 100 wipes, taking care that the impactor parts are not contaminated with ambient dust, oils, or fibers.

(3) Assemble the impactor as specified in the manufacturer's operating manual. To reduce the cumulative error caused by multiple weighings, eliminate the three stages that separate less than 2.5 μm particle sizes. The backup filter may be moved forward to eliminate unnecessary stages and the remaining stages may be loaded without substrates behind the backup filter, or a suitable spacer may be used.

(4) Seal each opening of the impactor with clean paraffin film or Teflon tape to prevent sample contamination until ready for use.

4.2.4 Test Apparatus:

4.2.4.1 Sample Filter: Load the sample filter into the test apparatus as specified in VDI Method 3926.

4.2.4.2 Absolute Filter Assembly With Untared Filters: Load the absolute filter with an untared filter as specified in VDI Method 3926.

4.2.4.3 Test Dust: Load the dust feed hopper with a sufficient quantity of test dust for the phase of testing being performed.

4.2.4.4 Cleaning: Prior to each test series, detach the raw-and clean-gas channels and wash the apparatus using water or a suitable solvent. Wipe the surfaces of the raw-gas channel clean with a dust-free rag. Use Class 100 wipes to clean the surfaces of the clean-gas channel. Thorough cleaning of the test apparatus is necessary to prevent interference caused by dust reentrainment.

4.3 Preliminary Determinations

4.3.1 Trial Operation: Prior to each test series, determine the instrument settings necessary to obtain a gas-to-cloth ratio of 1,000 Pa (4.0 fpm) and a dust feed rate of 34.4 ± 3.4 g/dscm (15.0 ± 1.5 gr/dscf). Perform this operation using an untared sample filter not to be used in the test series.

4.3.2 Reference Fabric Verification: Perform once per 3 months. Obtain a sample of reference fabric from:

APCT Program Office
Jack Farmer, RTI Program Manager
Research Triangle Institute
3040 Cornwallis Road
Research Triangle Park, NC 27709-2194

Verify the performance of the test apparatus by performing a complete test series using the reference fabric and the procedures herein. The reference fabric verification is acceptable if the following criterion is met:

mass gain of test sample filter: TBD + TBD grams

In the event that the above criterion is not met, adjust the test apparatus and repeat the reference fabric verification.

4.3.3 Test Dust Verification: Perform once on each dust shipment. Three test runs using an Andersen Impactor or equivalent are necessary to verify the test dust as specified in Section 3.2.

(1) Prepare the test apparatus as specified in Section 4.2.4. Use an untared sample filter that will not to be used in the test series.

(2) Prepare the impactor for isokinetic sampling as specified in the manufacturer's operating manual using all the available stages. Equip the impactor with a stainless steel sampling nozzle capable of isokinetic sample withdrawal from the raw-gas channel. Note, custom sampling nozzles are required for isokinetic sampling in this application. In the development of this method, a nozzle having a sample opening of 1.895 in. was required to maintain isokinetic sampling at a sample rate of 6 L per minute.

(3) Insert the nozzle into the raw-gas channel upstream of the test filter. The nozzle shall be located at least 2 in. from the channel walls. A bulkhead fitting is recommended between the nozzle and impactor body to seal the nozzle in place with the nozzle inside and the impactor housing outside of the raw gas channel.

(4) Operate the impactor at a sample rate of 3.5-7.0 L (0.1-0.2 ft^3) per minute for a sample duration of 2-3 minutes. A total sample volume of 10-20 L (0.28-0.57 ft^3) is recommended.

(5) Follow the impactor preparation, sample recovery, and analyses procedures in Sections 4.2.2, 4.2.3, and 4.5.2 and in the manufacturer's operating manual.

(6) Using the data reduction procedures in the manufacturer's operating manual, calculate the mass mean diameter and weight percent < 2.5 *u*m for the test dust.

(7) Repeat procedures (1) through (6), above, to obtain three valid test runs.

In the event that the mass mean diameter and weight percent < 2.5 *u*m do not meet the criteria of Section 3.2, the test dust or dust feed system must be corrected and the dust feed verified prior to testing.

4.3.4 Dust Feed Quick-Check: Perform once during the first conditioning period of each test series following the procedures specified in Section 4.3.3, steps (1) through (6). Confirm the dispersion of the dust in the raw-gas channel using an Andersen impactor. The dust feed quick-check shall consist of a single particle size measurement. In the event that the mass mean diameter and weight percent < 2.5 μm do not meet the criteria of Section 3.2, it is likely that dust agglomeration is present and adjustments must be made to the dust feed system and the verification test series repeated.

4.4 Verification Test Series

Perform one verification test series consisting of three test runs for each fabric tested. A test run consists of the following test phases.

4.4.1 Conditioning Period: Prepare the test apparatus as specified in Section 4.2.4. Subject the fabric to 10,000 pulses at 3 ± 1 second intervals under the following conditions:

dust loading:	34.4 ± 3.4 g/dscm (15.0 ± 1.5 gr/dscf), calculated on a block average for each 60 consecutive minutes during the test and for the last 60 minutes of each test. For example, if a test ran 125 minutes, measurements would get averaged for 1-60, 61-120, and 66-125 minutes.
gas-to-cloth ratio:	1,000 Pa ± 0.127 cm w.g (4.0 ± 0.2 ft/min), calculated on a block average for each 60 consecutive minutes during the test and for the last 60 minutes of each test.

At a minimum, the following parameters must be measured and recorded to confirm that the above requirements are met:

Parameter	Units	Minimum Recording Frequency
Fabric Pressure Drop	Pa or in. H_2O	1 second
Raw-Gas Flow*	m^3/hr	1 minute
Clean-Gas Flow*	m^3/hr	1 minute
Dust-Feed Weight	grams	1 minute

*Includes measurement of barometric pressure and humidity (which shall be taken once per test day) gas temperature, and static pressure (which shall be taken once per minute).

The conditioning period may be stopped and restarted provided that the above conditions are met. In the event that the above requirements are not met, the test run is void and repeated using a new sample filter.

4.4.2 Fabric Recovery Period: Continue to operate the test apparatus under the conditions specified in Section 4.4.1, except subject the fabric to normal pulsing for 30 filtration cycles. The fabric recovery period does not need to immediately follow the conditioning period, but must proceed without additional handling, dust loading, or pulsing of the sample filter. During the fabric recovery period, ensure that the dust loading and gas-to-cloth requirements of Section 4.4.1 are met. In the event these requirements are not met, the test run is void and repeated using a new sample filter.

4.4.3 Performance Test Period:

4.4.3.1 Preparation: Prior to each performance test period, load the test apparatus with dust. Load the impactor in place of the absolute filter as prepared by the procedures of Section 4.2.3.

4.4.3.2 Performance Testing: Operate the test apparatus as specified in Section 4.4.1, except subject the fabric to normal pulsing for a period of 360 minutes. Continue following the dust loading, gas-to cloth, and data capture and recording requirements of Section 4.4.1. In addition, record the following:

Parameter	Units	Recording Frequency
Filtration Cycle Time	seconds	Once per filtration cycle
Residual Pressure Drop	Pa or in. H_2O	Once per filtration cycle

In the event that the dust loading and gas-to-cloth requirements of Section 4.4.1 are not met, the test run is void and repeated using a new sample filter.

4.5 Sample Recovery and Handling

4.5.1 Sample Filter: Following each test run:

(1) Manually pulse the sample filter 10 times while the test apparatus is not in operation. This will facilitate removal of the filter cake.

(2) Remove the filter assembly from the test apparatus and place it on a flat surface with the collection side up. Brush or wipe any excess dust from the filter assembly, taking care not to add weight to the sample filter.

(3) Remove the sample filter from the filter assembly and place the filter in its labeled weigh container.

(4) Weigh the sample filter to the nearest 0.01 g.

4.5.2 Impactor Substrates and Backup Filter:

(1) Remove the impactor assembly from the test apparatus and transport to a clean, dry surface.

(2) Recover each impactor stage or backup filter into the corresponding weigh foil using clean tweezers, taking care not to lose any of the sample. Brush any excess dust or substrate fibers that remain on the impactor stages into the weigh foils using the recovery brush.

(3) Condition the impactor samples using the procedures of Section 4.2.2.2.

(4) Record the post-weight of each impactor stage using the weighing and handling procedures of Section 4.2.2.3 and 4.2.2.4.

5.0 Calibrations

Perform the following calibrations for inclusion in the Verification Report referenced in Section 7.

5.1 Prior to Each Use (and hourly, if necessary)

5.1.1 High-Resolution Analytical Balance: Calibrate the high-resolution analytical balance and check the calibration using the 1 mg daily-check weight as specified in Section 4.2.2.3.

5.1.2 Flowmeter: The raw-gas channel and clean-gas channel flowmeters will be checked according to 40 CFR 60, Appendix A, Method 5, Section 4.4.1. If the pretest check deviates by more than 3 %, the flow meter must be recalibrated.

5.2 Prior to Each Test Series

5.2.1 Dust-Feed Weight Measurement Device: With the dust-feed hopper empty, check the calibration of the dust-feed weight measurement device by placing the 2-3 kg span weight into the weigh hopper. It may be necessary to protect the span weight using a tared Ziploc™ plastic bag or equivalent. The dust-feed weight measurement device shall display a weight increase within 10 g of span weight plus the protective bag.

5.2.2 Low Resolution Analytical Balance: Check the calibration of the low resolution analytical balance using the 100 g span weight. The low resolution analytical balance shall display within 0.05 g of the calibration weight.

5.2.3 Pressure Transducers: Calibrate each pressure transducer against an oil manometer to within 0.1 in. w.g. The pressure transducers shall be calibrated at three points, zero, maximum, and at an intermediate pressure typically encountered during the test program. A simulated pressure may be produced using a squeeze bulb and a vice.

5.3 Every 3 Months

5.3.1 Microbalance: Use an independent set of ASTM Class 1 or 2 mass reference standards for the quality control check. These weights must be traceable to NIST with a tolerance of no more than 25 μg. Individual weights approximating substrate weights are suggested. Do not use the same weights for the QC check as are used for the day-to-day calibration verifications of the microbalance. The balance display shall agree with the certified value of the QC check weight to within ± 50 µg (twice the individual tolerance for ASTM Class 1 or 2 standards).

5.3.2 Calibrated Orifice of Hotwire Anemometer: Calibrate all flow measurement devices against a wet test meter or calibrated dry gas meter as referenced in 40 CFR 60, Appendix A, Method 5, Section 5.3 or 7.1. Calibrate the clean-gas flow measurement device at a single point corresponding to a flow of 0.76 ± 0.04 cfm (ft^3/min equivalent to a gas-to-cloth ratio of 4/1). Calibrate the raw gas flow measurement device at a flow of 4.5 ± 0.22 m^3/hr (2.65 ± 0.13 ft^3/min). Conduct each calibration for a minimum of 10 minutes. Use a calibration factor to adjust the signal to that of the wet test meter of calibrated dry gas meter.

5.3.3 Thermocouple in Raw-Gas Channel: Remove the thermocouple from the raw-gas channel and calibrate it against an ASTM mercury-in-glass reference thermometer at 74 ± 4°F. Alternatively, calibrate the thermocouple at a thermometric fixed point above and below 74 ± 4 °F (for example use an ice bath and boiling deionized distilled water, correcting the reference temperatures for barometric pressure). The thermocouple must agree with the reference point to within ± 1 °F.

5.3.4 Aneroid Barometer (if used): If a mercury barometer is not used, calibrate the aneroid barometer against a mercury barometer every 6 months. The aneroid barometer shall agree with the mercury barometer to the nearest 0.2 in. Hg.
5.3.5 Pressure Drop Measurement Device: Conduct a QC check of the instrument used to measure the pressure drop across the fabric specimen. This QC check must be done at least quarterly and the pressure-drop instrument shall be checked against a reference pressure standard that has been certified against NIST-traceable standards within the past year. The pressure-drop instrument and the reference pressure standard shall agree to within ± 0.25 cm (0.1 in.) w.g.
5.3.6 Timer Clock: The timer clock shall be calibrated quarterly to NIST time, which is obtained from the WWV radio reference signal or from the NIST World Wide Web site. If the timer clock is not within 1-second agreement with the WWV or website signal over a 1-hour period, the timer must be replaced with a unit that meets calibration requirements.
5.3.7 Flow Measurement: ETS will conduct a quality control check of the flow rates in the vertical raw-gas channel and in the clean-gas channel on at least a quarterly basis. The quality control check shall use a standard pitot tube that has been certified against NIST-traceable standards within the past year. The clean-gas flow rate shall be set to a nominal value corresponding to a filtration velocity of 73.1 m/hr (4.0 fpm) ± 15 %. The raw-gas flow rate shall be set to a nominal value of 5.8 m^3/hr (3.4 cfm) ± 5 %. Calculate the actual volumetric flow rates through the raw-gas channel and the clean-gas channel based on the pitot tube readings. The actual flow rate and the flow rate indicated by the raw-gas channel flowmeter shall agree to within ± 0.23 m^3/hr (0.14 cfm). The corresponding flow rates in the clean gas channel shall agree to within ± 0.06 m^3/hr (0.04 cfm).

5.4 Once per Year

5.4.1 Humidity and Temperature: Either calibrate the continuous humidity and temperature measurement device according to the manufacturer's specifications or obtain a manufacturer's calibration certificate.
5.4.2 Flowmeter: Calibrate the raw-gas channel and clean-gas channel flowmeters at least annually according to 40 CFR 60, Appendix A, Method 5, Section 7.1.1. The flowmeters shall be calibrated at three different flow rates that bracket their normal operating range. The reference standard for the calibration shall be a spirometer/bell prover or a wet test meter that has been certified against NIST-traceable standards within the past year.

6.0 Calculations

6.1 Nomenclature, Unit Conversions, and Equivalence Values

6.1.1 Nomenclature

A_f	=	Exposed area of sample filter, ft^2
C_a	=	Actual outlet particulate concentration of total mass, gr/ft^3
$C_{2.5a}$	=	Actual outlet particulate concentration of PM 2.5, gr/ft^3
C_s	=	Outlet particulate concentration corrected for standard conditions, gr/scf
C_{sd}	=	Outlet particulate concentration corrected for dry standard conditions, gr/dscf
d	=	Diameter of exposed area of sample filter, ft
E_t	=	Media efficiency for total mass, %
$E_{2.5}$	=	Media efficiency for PM 2.5, %

F_a	=	Actual dust feed rate, gr/ft^3
F_s	=	Dust feed rate corrected for standard conditions, gr/scf
F_{sd}	=	Dust feet rate corrected for dry standard conditions, gr/dscf
G/C	=	Gas-to-cloth ratio, ft/min
M_t	=	Total mass gain from Andersen Impactor, g
$M_{2.5}$	=	Total mass gain of particles less than 2.5 *u*m in diameter from Andersen Impactor, g (may need to be linearly interpolated from test data)
N	=	Number of filtration cycles in a given performance test period
ΔP_i	=	Residual pressure drop for filtration cycle i, in. W.C.
ΔP_{avg}	=	Average residual pressure drop, in. W.C.
P_{ba}	=	Barometric pressure, in. Hg
P_s	=	Absolute gas pressure in the stack, in. Hg
P_{static}	=	Average gas pressure, in. W.C.
Q_a	=	Actual gas flow rate through clean-gas channel, cfm
Q_{at}	=	Actual gas flow rate through clean-gas channel for a specific averaging time, t, cfm
T_a	=	Ambient temperature, °F
T_s	=	Stack (duct) temperature, °F
t	=	Specified averaging time or sampling time, min
t_c	=	Average filtration cycle time, sec.
w_f	=	Weight of dust in feed hopper following the specified time, g.
w_i	=	Weight of dust in feed hopper prior to the specified time, g.
$X_{2.5}$	=	Percent, by weight of PM 2.5 in the raw-gas dust feed as measured during the dust verification.

6.1.2 Unit Conversions

To convert to in. w.g. from in Hg, multiply by 13.6.
To convert to grains from pounds, multiply by 7000.
To convert to ft^3 from m^3, multiply by 35.313.
To convert to grams from pounds, multiply by 453.59.
To convert to seconds from minutes, multiply by 60.

6.1.3 Equivalence Values

Standard atmospheric pressure, in. Hg, = 29.92.
Standard temperature at 0 °F = 460 °R.
Standard temperature at 68 °F = 528 °R.

6.2 Area of Fabric - A_f

$$A_f = \frac{1}{4} \times \pi \times d^2$$

6.3 Gas-to-Cloth Ratio - G/C

$$G/C = \frac{Q_a}{A_f}$$

6.4 Absolute Pressure of Flue Gas - P_s

$$P_s = P_{ba} + \frac{P_{static}}{13.6}$$

6.5 Actual Dust Feed Rate - F_a, for a specified time - t

$$F_a = \frac{(w_i - w_f)}{Q_{at} \times t}$$

6.6 Dust Feed Rate at Standard Temperature and Pressure - F_s

$$F_s = F_a \times \left[\frac{(T_s + 460) \times 29.92}{P_s \times 528} \right]$$

6.7 Dry Dust Feed Rate at Std. Temperature and Pressure - F_{sd}

$$F_{sd} = \frac{F_s}{\left(1 - \frac{\%H_2O}{100}\right)}$$

6.8 Outlet Particulate Concentration, Total Mass - C_a

$$C_a = \frac{M_t}{Q_a \times 35.313 \times t} \times \frac{7000}{453.593}$$

6.9 Outlet Particulate Concentration, PM-2.5 - $C_{2.5a}$

$$C_{2.5a} = \frac{M_{2.5}}{Q_a \times 35.313 \times t} \times \frac{7000}{453.593}$$

6.10 Outlet Particulate Concentration at Standard Temperature and Pressure - C_s

$$C_s = C_a \times \left[\frac{(T_a + 460) \times 29.92}{P_s \times 528} \right]$$

6.11 Outlet Particulate Concentration at Dry Std. Temperature and Pressure - C_{sd}

$$C_{sd} = \frac{C_s}{\left(1 - \frac{\%H_2O}{100}\right)}$$

6.12 Filtration Cycle Time - t_c

$$t_c = \frac{t * 60}{N}$$

6.13 Average Residual Pressure Drop - $\Delta P_{av\,g}$

$$\Delta P_{avg} = \frac{\sum_{i=1}^{N} \Delta P_i}{N}$$

7.0 Verification Report

A fully documented test report is required. The verification report shall adhere to the format as specified in the *Generic Verification Protocol for the Baghouse Filtration Products* and the Test/QA Plan.

SOP, ATTACHMENT A

Example Data Sheets

BAGHOUSE FILTRATION PRODUCTS
VERIFICATION TESTING

TEST RUN ID: ____________________

TEST FACILITY: ____________________

____

FABRIC ID: ____________________

DUST: ____________________

CONDITIONING - 0-10000 PULSES

DATE: ____________________

START TIME: ____________________

STOP TIME: ____________________

RUN TIME: ____________________

AMBIENT CONDITIONS

Temperature (F): ____________________

Pressure (in. Hg): ____________________

Wet Bulb (F): ____________________

Humidity: ____________________

TEST CONDITIONS

	Initial Mass (g)	Final Mass (g)	Dust Feed (g)	Raw Gas Flow (ft^3)	Clean Gas Flow (ft^3)	Total Gas Flow (ft^3)	Dust Feed (g/ft^3)	G/C Ratio (ft/min)
0-60 min.								
61-120 min.								
121-180 min.								
181-240 min.								
241-300 min.								
301-360 min.								
361-420 min.								
421-480 min.								
___-___ min.								

Operator Signature: ____________________

BAGHOUSE FILTRATION PRODUCTS
VERIFICATION TESTING

TEST RUN ID: ____________________

TEST FACILITY: ____________________

____

FABRIC ID: ____________________

DUST: ____________________

FABRIC RECOVERY - 10000-10030 PULSES

DATE: ____________________

START TIME: ____________________

STOP TIME: ____________________

RUN TIME: ____________________

AMBIENT CONDITIONS

Temperature (F): ____________________

Pressure (in. Hg): ____________________

Wet Bulb (F): ____________________

Humidity: ____________________

TEST

	Initial Mass (g)	Final Mass (g)	Dust Feed (g)
0-60 min.			
61-120 min.			
121-180 min.			
___-___ min.			

	Raw Gas Flow (ft^3)	Clean Flow (ft^3)	Total Gas Flow (ft^3)	Dust Feed (g/ft^3)	G/C Ratio (ft/min)
0-60 min.					
61-120 min.					
121-180 min.					
___-___ min.					

Operator Signature: ____________________

ETS, Inc.

BAGHOUSE FILTRATION PRODUCTS
VERIFICATION TESTING

TEST RUN ID: ____________________
TEST FACILITY: ____________________
____

FABRIC ID: ____________________
DUST: ____________________

PERFORMANCE TEST PERIOD
DATE: ____________________
START TIME: ____________________
STOP TIME: ____________________
RUN TIME: ____________________

AMBIENT CONDITIONS
Temperature (F): ____________________
Pressure (in. Hg): ____________________
Wet Bulb (F): ____________________
Humidity: ____________________

TEST

	Initial Mass (g)	Final Mass (g)	Dust Feed (g)
0-60 min.			
61-120 min.			
121-180 min.			
181-240 min.			
241-300 min.			
301-360 min.			

	Raw Gas Flow (ft^3)	Clean Flow (ft^3)	Total Gas Flow (ft^3)	Dust Feed (g/ft^3)	G/C Ratio (ft/min)
0-60 min.					
61-120 min.					
121-180 min.					
181-240 min.					
241-300 min.					
301-360 min.					

Operator Signature: ____________________

ETS, Inc.

HIGH RESOLUTION ANALYTICAL BALANCE DATA SHEET
(USE ONE PER IMPACTOR SET)

TEST FACILITY: ____________________
IMPACTOR SET ID: ____________________
FABRIC ID: ____________________
TEST RUN ID: ____________________

PRE-WEIGHING			POST-WEIGHING		
Date:	____________		Date:	____________	
Start Time:	____________		Start Time:	____________	
Stop Time:	____________		Stop Time:	____________	

CONDITIONING	Date	Time	CONDITIONING	Date	Time
Conditioning Start:			Conditioning Start:		
Conditioning Stop:			Conditioning Stop:		
Conditioning Successful?:	yes/no		Conditioning Successful?:	yes/no	
(Attach Temperature and Humidity Data)			(Attach Temperature and Humidity Data)		

CALIBRATION DATA:		CALIBRATION DATA:	
Time:		Time:	
Response to 1 g weight:		Response to 1 g weight:	
Within 0.00005 g?	yes/no	Within 0.00005 g?	yes/no

Stage	Pre-Mass* (g)	Post-Mass* (g)	Mass Gain (g)
0			
1			
2			
3			
4			
5			
6			
7			
8			
Filter			

* Including labeled weigh foils

Operator Signature: ____________________

ETS,

LOW RESOLUTION ANALYTICAL BALANCE AND WEIGH FEEDER DATA SHEET

TEST FACILITY: ____________________
IMPACTOR SET ID: ____________________
FABRIC ID: ____________________
TEST RUN ID: ____________________

WEIGH FEEDER SCALE
Date: ____________________
Calibration Wt. Value: ____________________
Tare Weight: ____________________

Tare + Calibration Wt.: ____________________
Calibration Weight
Within 10 g? Yes/No

LOW RESOLUTION BALANCE CALIBRATION
Date: ____________________
Response to 100 g ____________________
Within 0.05 g? Yes/No

Fabric Sample ID	Test Run ID

Pre-Mass (g)	Post Mass (g)	Mass Gain (g)

Operator Signature: ____________________

SOP, ATTACHMENT B

Example Verification Testing Spreadsheets

VERIFICATION TESTING OF BAGHOUSE FILTRATION PRODUCTS
DETAILED SUMMARY OF DATA AND RESULTS

CONDITIONING PERIOD

RUN ID.	A2-GT-CP	NUMBER OF PULSES	10000
FABRIC DESIGNATION	PTFE Membrane	PULSE INTERVAL	3 sec.
MANUFACTURER	NA	PULSE PRESSURE	0.52 MPa
DUST FEED	Alcoa A 152-SG		
DATE(S)	1/18/00 - 1/19/00		
TIME STARTED	16:30		
TIME ENDED	0:50		
TEST TIME	500 min.		

QA/QC DATA

Test Time (min.)	Time		Dust Feed (g) Initial	Final	Total	Average Gas Flow (sm^3/hr) Raw	Clean	Total	Avg. Temp (C)	Avg Press (mbar)	Dust Conc. (g/m^3)
0-60	16:30	17:30	2748.4	2346.5	401.9	4.43	1.07	5.50	24.30	973.87	69.2
61-120	17:31	18:30	2346.5	2121.2	225.4	4.45	1.06	5.51	25.22	973.94	38.6
121-180	18:31	19:30	2121.2	1705.5	415.7	4.45	1.06	5.51	25.48	974.11	71.2
181-240	19:31	20:30	1705.5	1296.4	409.1	4.45	1.06	5.51	25.48	974.22	70.1
241-300	20:31	21:30	1296.4	1300.1	-3.6	4.45	1.06	5.51	25.43	974.27	-0.6
301-360	21:31	22:30	1300.1	1069.6	230.5	4.45	1.06	5.51	25.40	974.37	39.5
361-420	22:31	23:30	1069.6	832.6	237.0	4.45	1.06	5.51	25.39	974.63	40.6
421-480	23:31	0:30	832.6	603.4	229.2	4.45	1.06	5.51	25.37	974.55	39.3
441-500	23:51	0:50	743.3	528.0	215.3	4.45	1.06	5.51	25.37	974.61	36.9
AVERAGE (per hour)			2748.4	528.0	266.4	4.45	1.06	5.51	25.26	974.26	50.6
ACCEPTANCE					206 +/- 20				25.5 +/- 2.2		34.4 +/- 3.4

DATA PROCESSING OPERATOR: ______________________
ETS, Inc.

VERIFICATION TESTING OF BAGHOUSE FILTRATION PRODUCTS
DETAILED SUMMARY OF DATA AND RESULTS

RECOVERY PERIOD

RUN ID.	A2-GT-RP	NUMBER OF PULSES	30
FABRIC DESIGNATION	PTFE Membrane	AVG. PULSE INTERVAL	304 sec.
MANUFACTURER	NA	AVG . RESIDUAL ΔP	139.6 Pa
DUST FEED	Alcoa A 152-SG	MAX. PRESSURE DROP	1000 Pa
DATE(S)	1/19/00	PULSE PRESSURE	0.52 MPa
TIME STARTED	7:18		
TIME ENDED	9:49		
TEST TIME	151.85 min.		

QA/QC DATA

Test Time			Dust Feed (g)			Average Gas Flow (sm^3/hr)			Avg. Temp	Avg Press	Dust Conc.	G/C Ratio
(min.)	Time		Initial	Final	Total	Raw	Clean	Total	(C)	(mbar)	(g/m^3)	(m/hr)
0-60	7:18	8:18	1911.3	1671.4	239.9	4.42	1.07	5.50	23.8	974.99	39.9	73.4
61-120	8:19	9:18	1671.4	1449.7	221.8	4.43	1.07	5.50	24.7	974.98	36.8	73.3
74-133	8:50	9:49	1553.8	1325.6	228.2	4.43	1.07	5.50	25.0	975.15	37.9	73.3
AVERAGE (per hour)			1911.3	1325.6	231.4	4.43	1.07	5.50	24.4	975.04	38.5	73.3
ACCEPTANCE					206				25.5		34.4	73.1
					+/- 20				+/- 2.2		+/- 3.4	+/- 3.6

DATA PROCESSING OPERATOR:______________________________

ETS, Inc.

VERIFICATION TESTING OF BAGHOUSE FILTRATION PRODUCTS
DETAILED SUMMARY OF DATA AND RESULTS

PERFORMACE TEST PERIOD

RUN ID.	A2-GT-PT	NUMBER OF PULSES	67
FABRIC DESIGNATION	PTFE Membrane	AVG. PULSE INTERVAL	317 sec.
MANUFACTURER	NA	AVG. RESIDUAL ΔP	149.3 Pa
DUST FEED	Alcoa A 152-SG	MAX. PRESSURE DROP	1000 Pa
DATE(S)	1/19/00	PULSE PRESSURE	0.52 MPa
TIME STARTED	10:18		
TIME ENDED	16:18		
TEST TIME	360 min.		

QA/QC DATA

Test Time (min.)	Time		Dust Feed (g) Initial	Final	Total	Average Gas Flow (sm3/hr) Raw	Clean	Total	Avg. Temp (C)	Avg Press (mbar)	Dust Conc. (g/m3)	G/C Ratio (m/hr)
0-60	10:18	11:18	2139.7	1927.1	212.6	4.40	1.07	5.47	25.21	975.63	40.8	73.3
61-120	11:19	12:18	1927.1	1698.7	228.4	4.41	1.07	5.47	25.85	975.32	43.6	73.4
121-180	12:19	13:18	1698.7	1479.1	219.6	4.41	1.07	5.47	26.30	974.55	41.9	73.6
181-240	13:19	14:18	1479.1	1252.8	226.4	4.41	1.07	5.48	26.58	973.70	43.1	73.9
241-300	14:19	15:18	1252.8	1028.4	224.4	4.41	1.07	5.48	26.78	973.33	42.7	74.1
301-360	15:19	16:18	1028.4	812.5	215.9	4.41	1.07	5.48	26.79	973.12	41.1	74.1
AVERAGE (per hour)			2139.7	812.5	221.2	4.41	1.07	5.47	26.25	974.28	42.2	73.7
ACCEPTANCE					206 +/- 20				25.5 +/- 2.2		34.4 +/- 3.4	73.1 +/- 3.6

GRAVIMETRIC DATA

IMPACTOR SUBSTRATES		SAMPLE FILTER	
Backup Filter (PM 2.5)	0.00077 g	Tare Mass	11.87 g
Total Mass Gain	0.00159 g	Final Mass	12.07 g
		Mass Gain	0.20 g

OUTLET CONCENTRATION

Total Volume Sampled	6.86 m3
Mean Outlet Particle Concentration - PM 2.5	0.00011 g/m3
Mean Outlet Particle Concentration - Total Mass	0.00023 g/m3

DATA PROCESSING OPERATOR:

ETS, Inc.

VERIFICATION TESTING OF BAGHOUSE FILTRATION PRODUCTS
SUMMARY OF RESULTS

RUN ID.	**A-GT**	**A2-GT**	**A3-GT**	Average
FABRIC DESIGNATION	**PTFE Membrane**	**PTFE Membrane**	**PTFE Membrane**	
MANUFACTURER	**NA**	**NA**	**NA**	
DUST FEED	**Alcoa A 152-SG**	**Alcoa A 152-SG**	**Alcoa A 152-SG**	
QUICKCHECK				
Mass Mean Diameter	1.07			1.07
% Less than PM 2.5	74.41			74.41
CONDITIONING PERIOD				
Date Started	1/13/00 - 1/14/00	1/18/00 - 1/19/00	1/19/00 - 1/20/00	
Time Started	16:15	16:30	17:40	
Time Ended	0:35	0:50	2:00	
Test Time (min.)	500	500	500	500
RECOVERY PERIOD				
Date Started	1/17/00	1/19/00	1/20/00	
Time Started	9:15	7:18	7:46	
Time Ended	11:27	9:49	10:19	
Test Time (min.)	133	152	154	146
PERFORMANCE TEST PERIOD				
Date Started	1/17/00	1/19/00	1/20/00	
Time Started	12:55	10:18	10:29	
Time Ended	18:55	16:18	16:29	
Test Time (min.)	360	360	360	360
VERIFICATION TEST RESULTS				
Mean Outlet Particle Conc. PM 2.5 (g/dscm)	0.0002011	0.0001182	0.0001197	0.0001463
Mean Outlet Particle Conc. Total mass (g/dscm)	0.0003493	0.0002472	0.0001850	0.0002605
Change in Residual Pressure Drop (cm w.g.)	4.10	4.07	4.20	4.12
Average Residual Pressure Drop (cm w.g.)	2.03	1.52	2.11	1.89
Mass Gain of Filter Sample (g)	0.18	0.2	0.23	0.20
Average Filtration Cycle Time (sec.)	199	317	313	276

DUST CHARACTERIZATION SAMPLING

RUN NUMBER	A-GT						
DATE	1/19/00		DATA (FOR RAW GAS CHANNEL)				
START TIME	11:27		Actural Flow			5.77	m^3/hr
END TIME	11:32					3.40	cfm
STACK LENGTH	111	mm	Std. Flow			5.49	sm^3/hr
STACK WIDTH	291	mm				3.23	scfm
STACK AREA	0.0323	m^2	Raw Gas Pressure			980.15	mbar
NOZZLE I.D.	1.797	in.	Sample Gas Temperature			25.2	°C
	0.046	m				77.4	°F
METER BOX GAMMA	0.9927						
BAROMETRIC PRESSURE	28.93	in. Hg					
TEST DURATION	5	min.					
METER VACUUM	2.0	in. Hg					
INTERMEDIATE RESULTS			**METHOD 3 DATA**				
Metered Volume	0.920	ft^3	%O2	20.9	Md	28.84	
Volume @ Std. Cond.	0.833	scf	%CO2	0.0	Ms	28.72	
Volume at Raw Gas Conditions	0.929	scf	%CO2	0.0	Ps	28.94 In. Hg	
Water	1.06	%	%N2	79.1			
Isokinetics	107.9	%	O2+CO2	20.9			

POINT	STACK TEMP (°F)	STATIC PRESSURE (in. w.g.)	DP (in. w.g.)	DH (in. w.g.)	METER VOLUME (liters)	METER TEMPERATURE INLET (°F)	OUTLET (°F)
1	77.4	-0.1	0.00	6.125	5226.81	76	74
					5252.85	80	75
AVG.	77.4	-0.1	0.00	6.125	26.04	76 (Avg. of 4 temps.)	

DH - Orifice Pressure Drop
DP - Pressure Drop
Md - Dry Molecular Weight
Ms - Molecular Weight in Stack
Ps - Static Pressure

All measurements are primary measurements and may be converted to other units in subsequent calculations

RTI/ETV PRELIMINARY TESTING
DUST CHARACTERIZATION - PURAL NF
ANDERSEN IMPACTOR PARTICLE SIZING
GRAVIMETRIC ANALYTICAL DATA AND RESULTS

RUN NUMBER: A2-GT-PT
TEST DATE: 01/19/00

Sample I.D. Filter I.D.	Wash Vol.(ml)	Stage	Tare Filter Mass (g)	Tare Beaker Mass (g)	Total Tare Mass (g)	Total Final Mass (g)	Mass Difference (g)	Negative Difference? (g)
VDI-99-14	50	Acetone Wash	NA	0	0	0	0.00000	NA
99-14-1		1	0.93719	0	0.93719	0.93854	0.00135	NA
99-14-2		2	0.85021	0	0.85021	0.85078	0.00057	NA
99-14-3		3	0.92495	0	0.92495	0.92683	0.00188	NA
99-14-4		4	0.86225	0	0.86225	0.86503	0.00278	NA
99-14-5		5	1.01371	0	1.01371	1.01939	0.00568	NA
99-14-6		6	0.91323	0	0.91323	0.92372	0.01049	NA
99-14-7		7	0.92345	0	0.92345	0.93370	0.01025	NA
99-14-8		8	0.88045	0	0.88045	0.88668	0.00623	NA
99-14-9		9	0.98456	0	0.98456	0.99213	0.00757	NA
						Total	0.04680	

IMPACTOR PARTICLE SIZING RESULTS

Impactor Flow Rate: 0.186 cfm
Isokinetics: 107.82 %
Viscosity of Gas: 0.000182 poise

STAGE	Particulate Mass (g)	Cummulative % Less Than Diameter	D50 Cut Point (micrometers)*
1	0.00135	97.12	10.85
2	0.00057	95.90	10.23
3	0.00188	91.88	6.39
4	0.00278	85.94	4.27
5	0.00568	73.80	2.41
6	0.01049	51.39	1.10
7	0.01025	29.49	0.68
8	0.00623	16.18	0.37
9	0.00757		

Mass Mean Diameter, micrometers 1.07
% Less Than PM 2.5 74.41

* Calculated as an aerodynamic diameter using a particle density of 1 g/cm3.